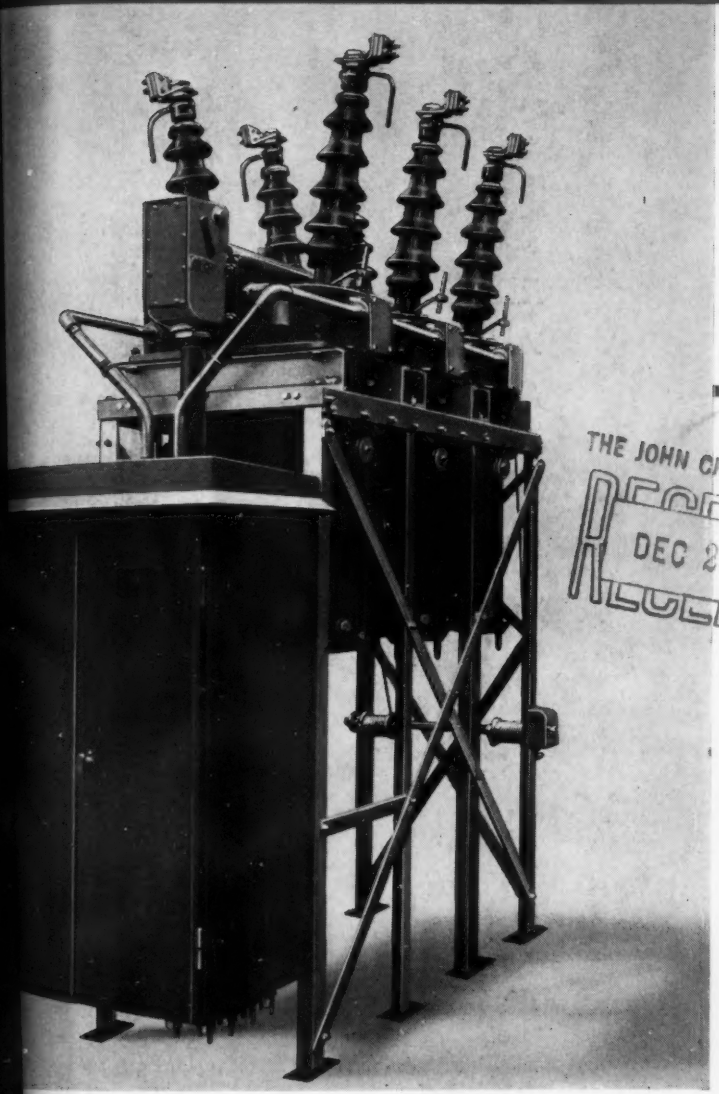
627

Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 DECEMBER 1953



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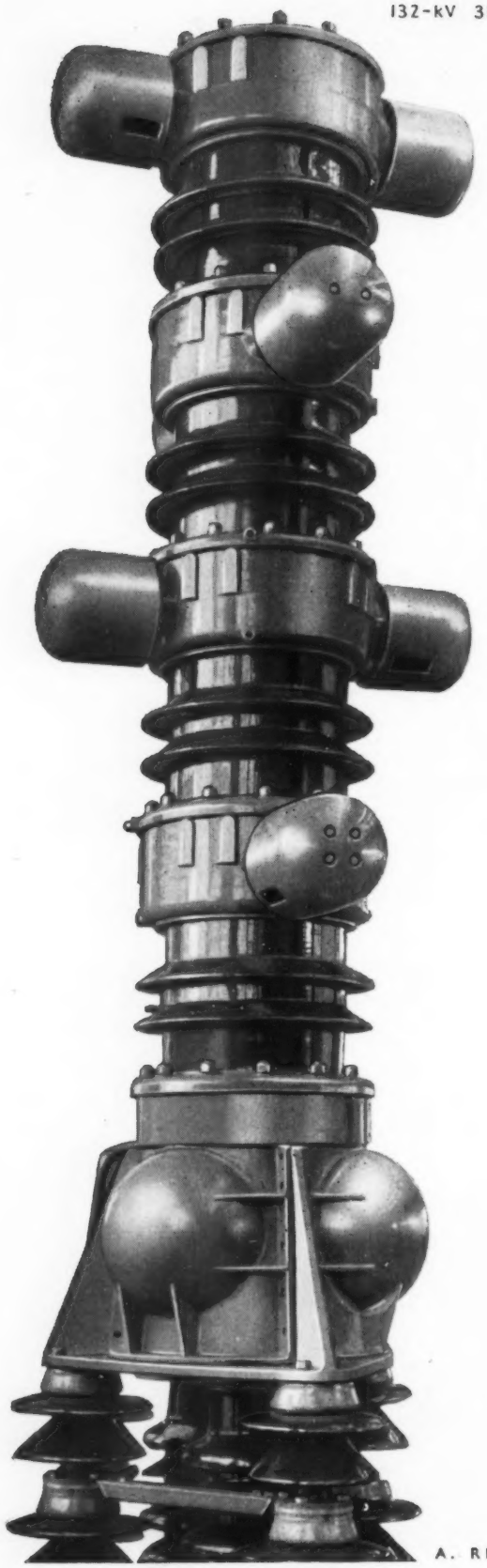

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One phase from one of twenty-three circuit-breakers installed at Barking 'C' power-station

Consulting Engineers: Messrs. MERZ and McLELLAN

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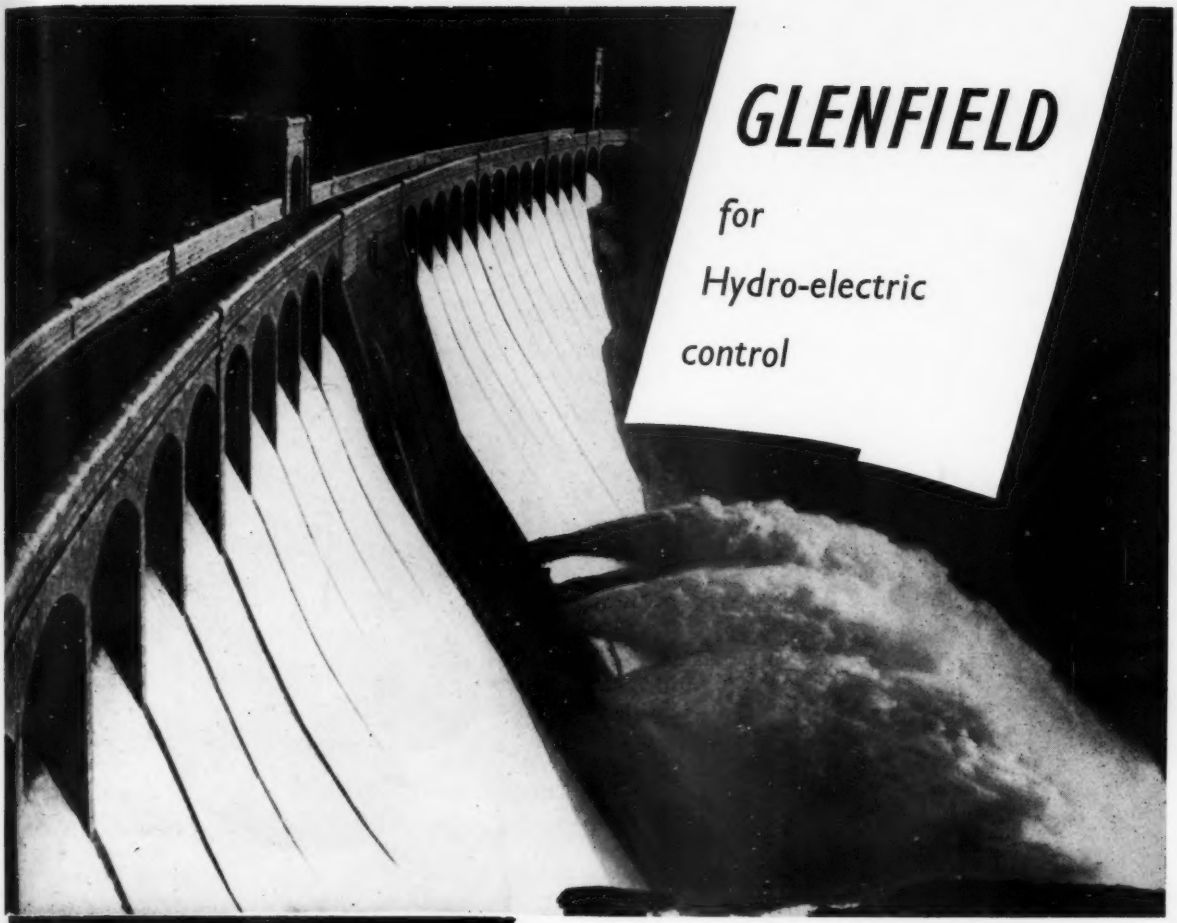

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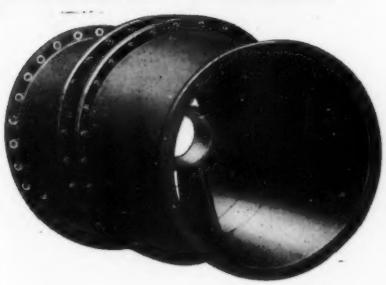
JET DISPERSERS



GLENFIELD JET DISPERSERS are in use throughout the world on points of free discharge.

On siphon spillways, scours and on compensation water outlets from dams and reservoirs, and washouts from pipelines.

To result in the harmless dissipation of the issuing jet, without vibration or erosion either of the disperser itself or of the area on which the discharge falls whether into river bed—tunnel—or ditch.

To render elaborate and costly protective works unnecessary.

The top illustration shows six jet dispersers on a siphon spillway each designed to discharge at the rate of 620 cubic feet of water per second to absorb in turn a total of 25,000 H.P. in the process.

Glenfield

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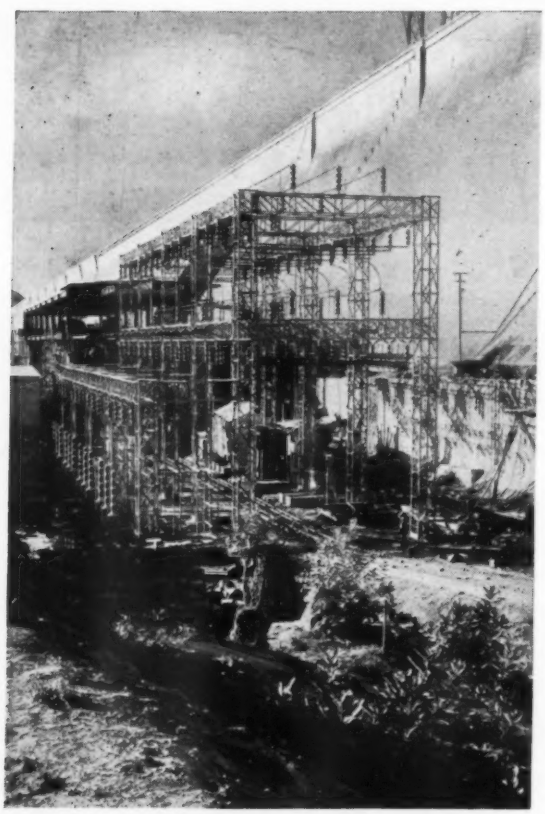
The Mettur Dam sub-station is one of many in South India equipped with posts type P.642 for 66KV and 110KV.



Photograph reproduced by courtesy of the main contractors, Messrs. A.E.I. (India) Ltd.

S.P.P. POST INSULATORS were specified for the METTUR DAM SUB-STATION MADRAS

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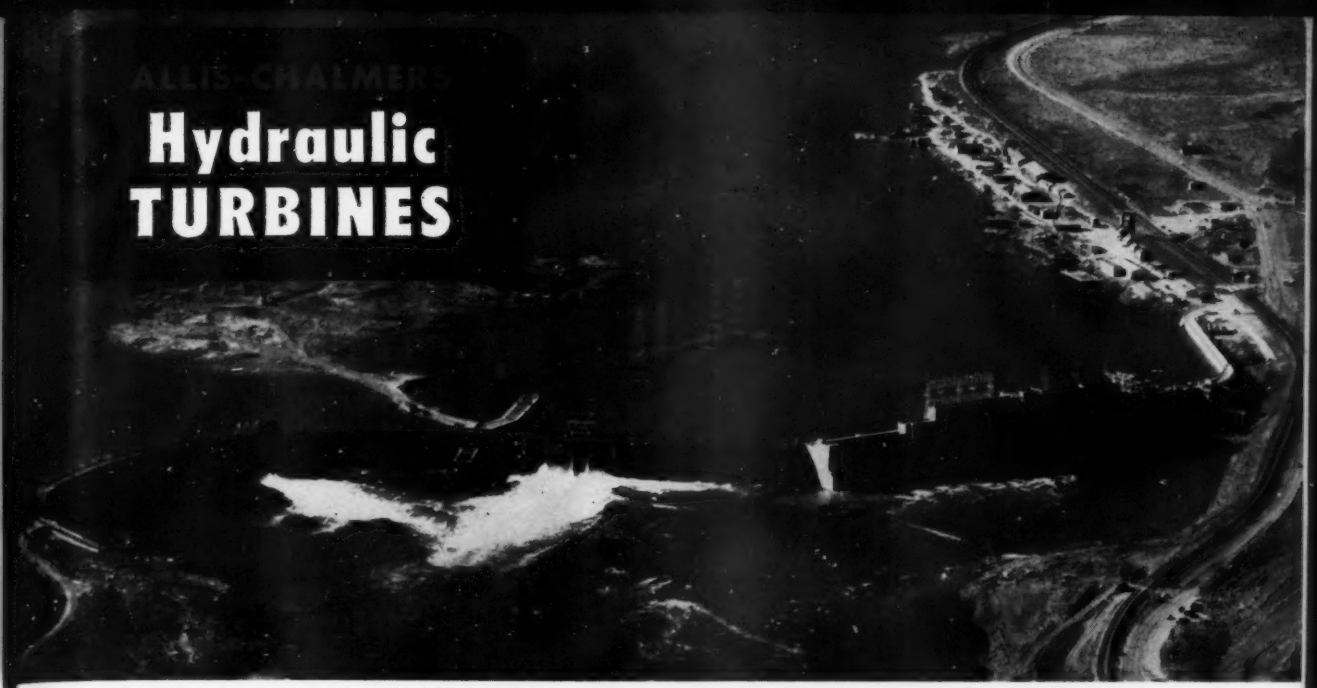

Closing a Power Gap

Six New 34,000-Hp Hydro-Electric Units Match Booming Industrial Power Demand

RECENT industrial growth in the United States Pacific Northwest region has been swift. So swift that electric power demand began to outrun the area's installed capacity. Prompt delivery of six 34,000-hp Allis-Chalmers turbines and generators for the Rock Island Plant on the Columbia River helped to close the power gap.

The Rock Island Plant originally went into operation in 1932 with four Allis-Chalmers propeller-type turbines rated 21,000 hp at 32 ft normal head. Subsequent raising of the Rock Island Dam by Public Utility District No. 1 of Chelan County provided a 45 ft normal head for the six 34,000-hp, 100-rpm, Kaplan-type adjustable-propeller turbines installed in 1952-1953.

With half a century of turbine building experience, A-C can furnish Francis, propeller or impulse-type turbines together with governors, regulators, valves, and synchronous or induction generators to suit any application. For your convenience, A-C has 95 sales offices and 65 distributors located in 53 countries. For more information ask for Bulletins 01B7301 and 05B7549. Allis-Chalmers, Milwaukee 1, Wisconsin, U.S.A.

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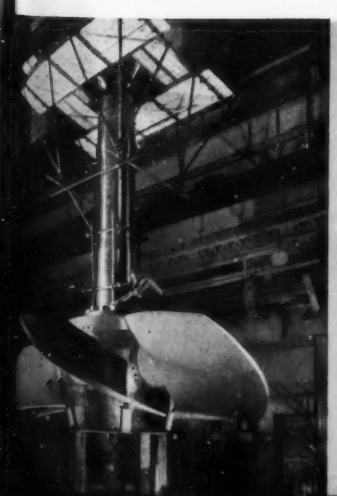
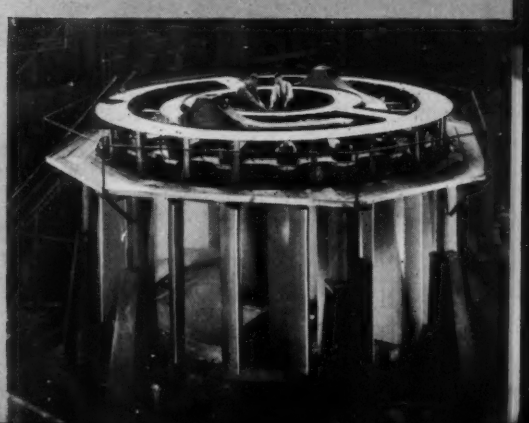


Aerial view above shows enlarged Rock Island Plant on Columbia River. Supplementing the four original 21,000-hp turbines, the six new 34-000-hp units drive 25,000-kva, 0.9-pf, 13,800-volt Allis-Chalmers generators, adding a capacity of 150,000 kva to serve growing industrial power requirements.

Views at left and right show the runner and internal parts for 34,000-hp units during shop assembly in the Allis-Chalmers plant.



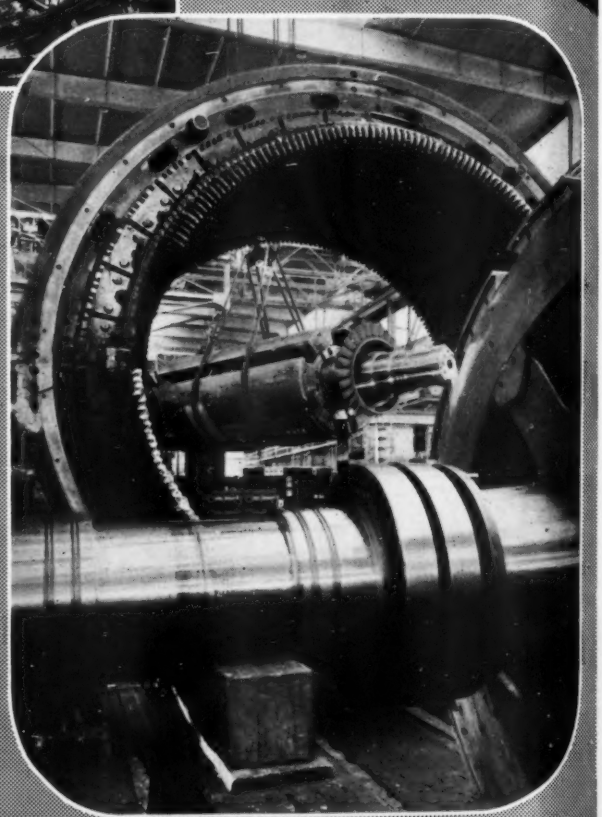
BROWN BOVERI

Precision and reliability

the basis of Brown Boveri products

Left: The Brown Boveri works at Baden (Switzerland).

Below: Stator and rotor of a 15300-kVA, 375-r.p.m. generator for a Norwegian power station, in the large assembly bay. At rear rotor of a 40000-kVA, 1000 r.p.m. synchronous capacitor.



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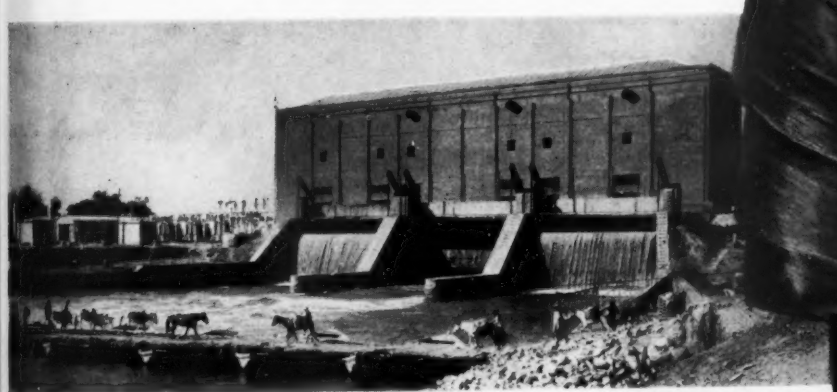
In India, where industry is making an ever-increasing demand for electrical power and where supply is being steadily extended to the rural areas, Boving water turbines are playing a major part in the production of hydro-electric power. The Uttar Pradesh Hydel Division which has many hydro-electric stations under their control, including the three illustrated here, have excellent experience of the reliability, easy maintenance and long life of Boving equipment.

The Bahadrabad hydro-electric station at the head of the Ganges Canal.

The Palra power station—another plant with Boving Kaplan turbines

(Below)
Muhammadpur Falls on the Ganges Canal is a station equipped with Boving plant throughout.



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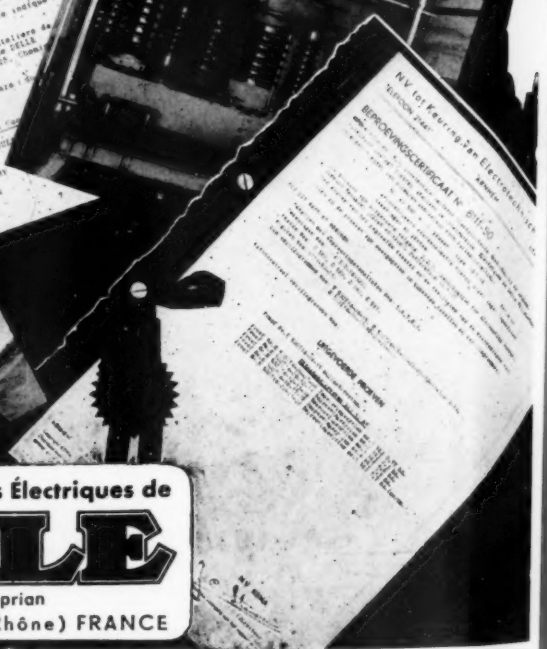

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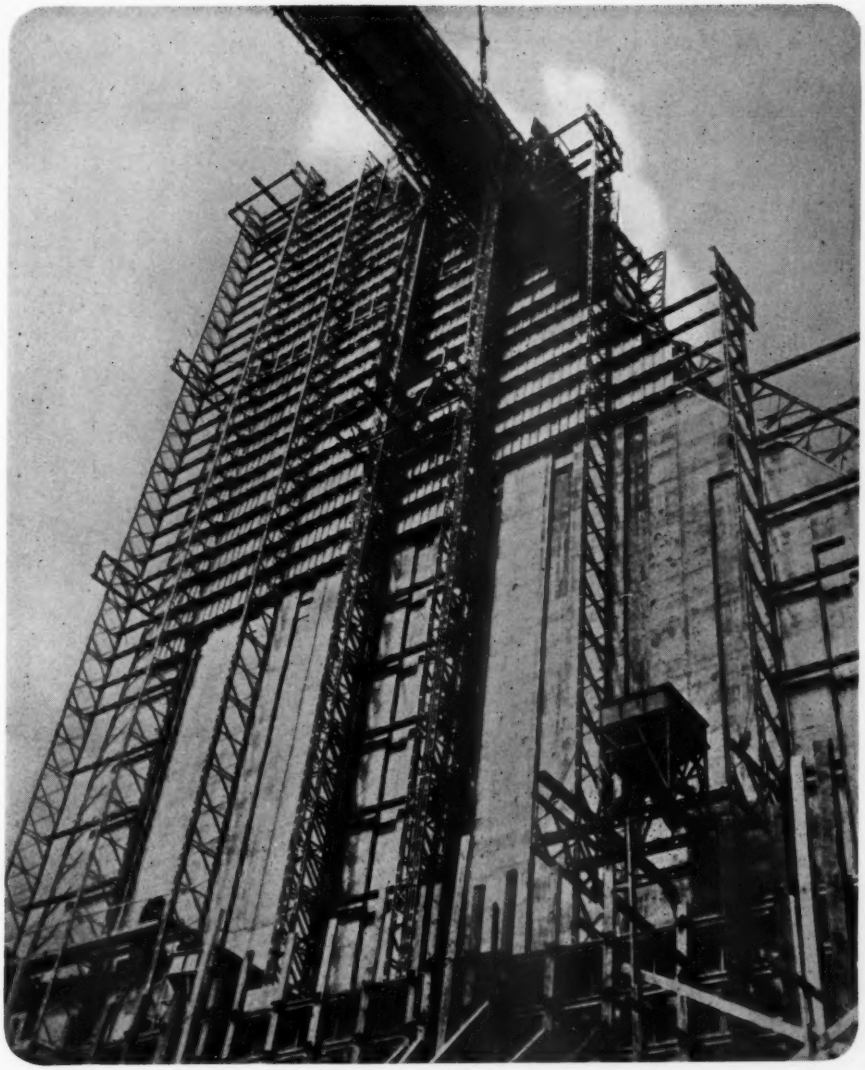

Photograph by courtesy of the Ontario Hydro Electric Commission

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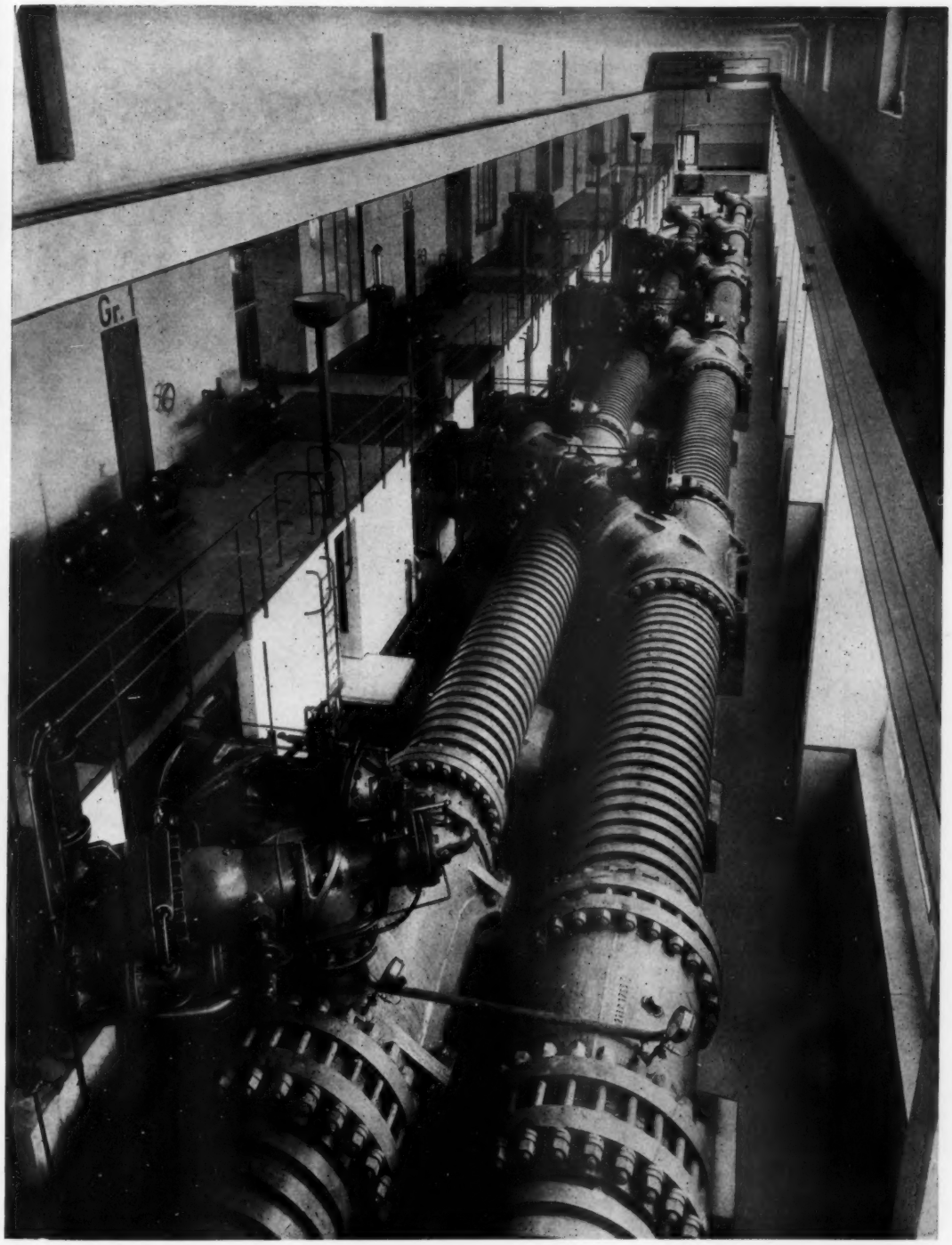

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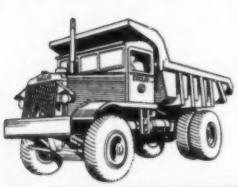
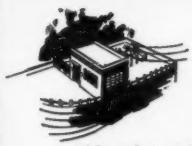


Subsidiary Companies Branches Works and Agencies throughout the World



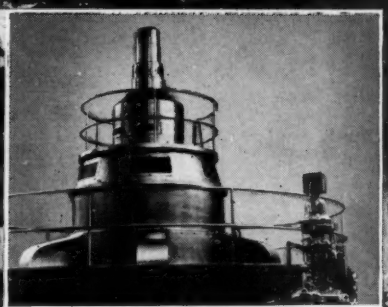
the lonesomest plant in Puerto Rico

Although Caonillas No. 1 is a busy plant—producing up to 22,000 kva, and running full blast—you seldom see a man in it. Completely automatic operation makes it the lonesomest plant in Puerto Rico.

There's not even a man around to check on operation. That's done by remote control 10 miles away at Dos Bocas power plant—nerve center for three stations of the Caonillas Hydro-electric Project which supplies power to all points in Puerto Rico. At Dos Bocas, operators can tell by a glance at the Westinghouse control panel what is happening at Caonillas No. 1.

Sixteen billion gallons of water for this station are stored behind a concrete dam built across Caonillas River. It's a straight gravity overflow type dam, 850 feet long at the crest, and 250 feet above river bed. A pressure tunnel conveys impounded water through solid rock to No. 1 power house 2½ miles downstream, where two Westinghouse vertical waterwheel generators produce inexpensive power for transmission to thriving San Juan, and for irrigation and standby service.

Caonillas project, conceived and built entirely by Puerto Rico Water Resources Authority under the general direction of Antonio Lucchetti, Executive Director, adds vital new output to the Authority's expanding electrical network. Working directly with Authority engineers, Westinghouse was able to apply broad technical knowledge and manufacturing skill in designing hydroelectric plants and remote control.



Two Westinghouse vertical waterwheel generators similar to this unit were installed at Caonillas—each 11,000 kva, 3-phase, 60-cycle, 4160 volts, 514 rpm. Westinghouse builds both vertical and horizontal types, in practically all frequencies, speeds and voltages. For further information on power generating and distributing apparatus write to Dept. Y.

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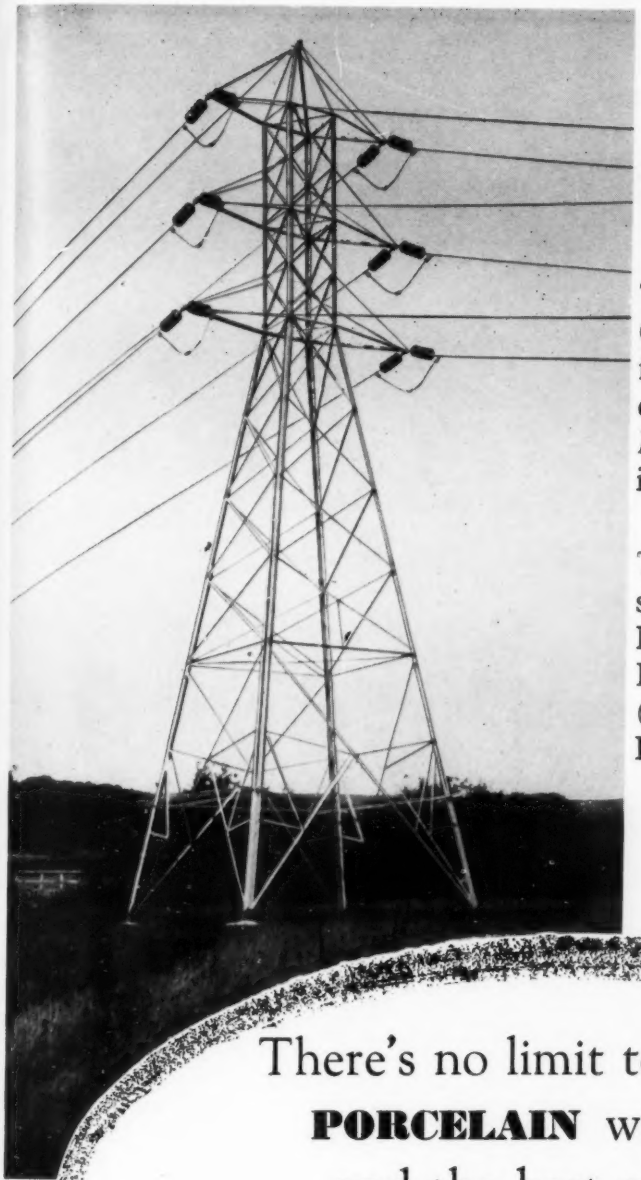

The photograph shows T.T. porcelain Cap and Pin Insulators on one of the first 66 kV Overhead Lines to be erected in the British Isles—a line from Maentwrog to Wrexham which is still in use after a quarter of a century.

Taylor Tunnicliff & Co. Ltd. will also supply the Insulators for the latest B.E.A. 275 kV Super Grid Line from Iver via Weybridge to Melksham. (Main Contractors: Balfour Beatty Co. Ltd.. London.)

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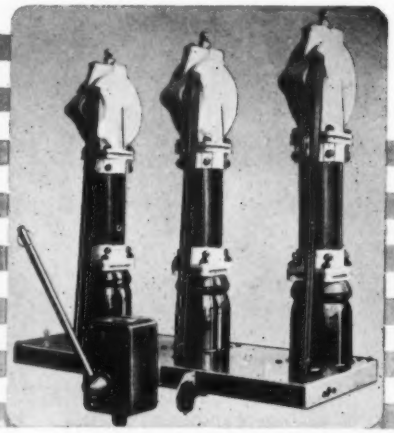
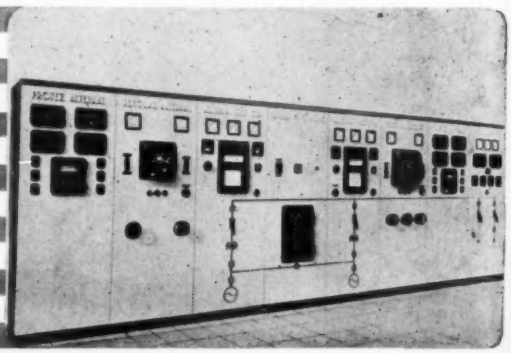
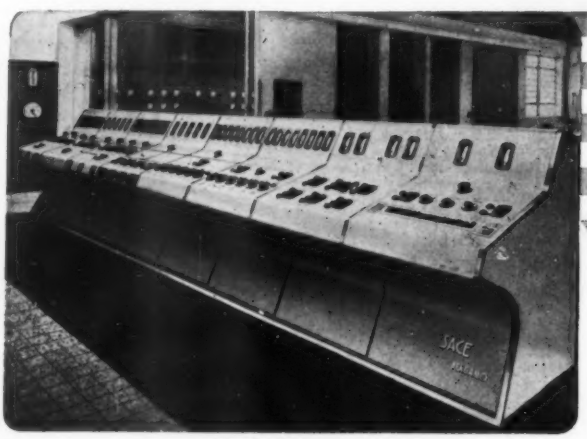


Industrial Plants
Shipboard Plants
Substations
Power Stations





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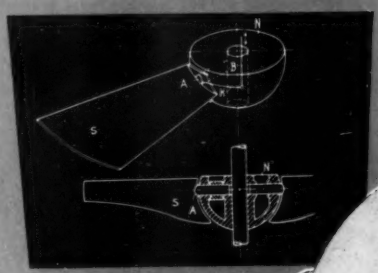
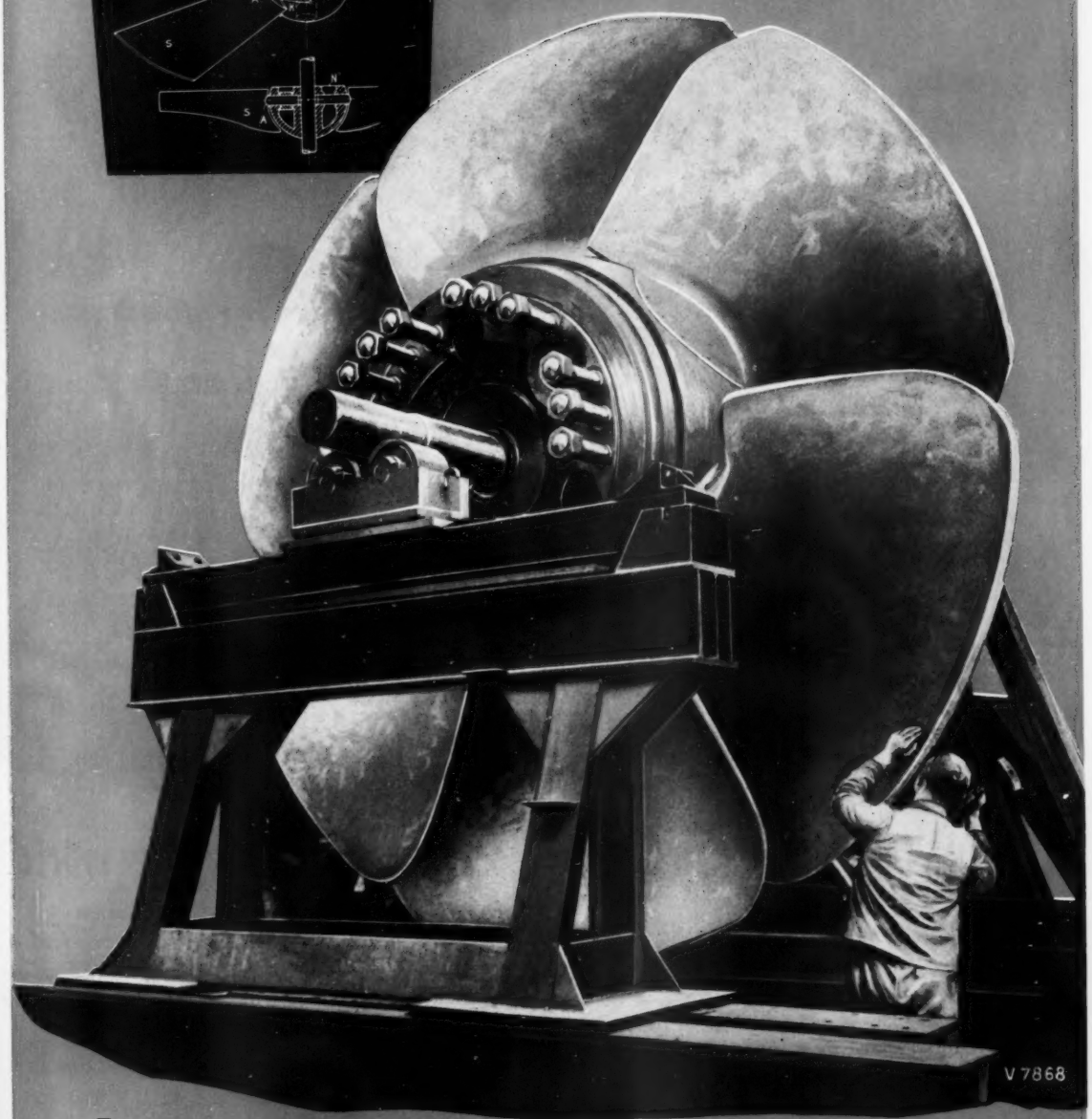
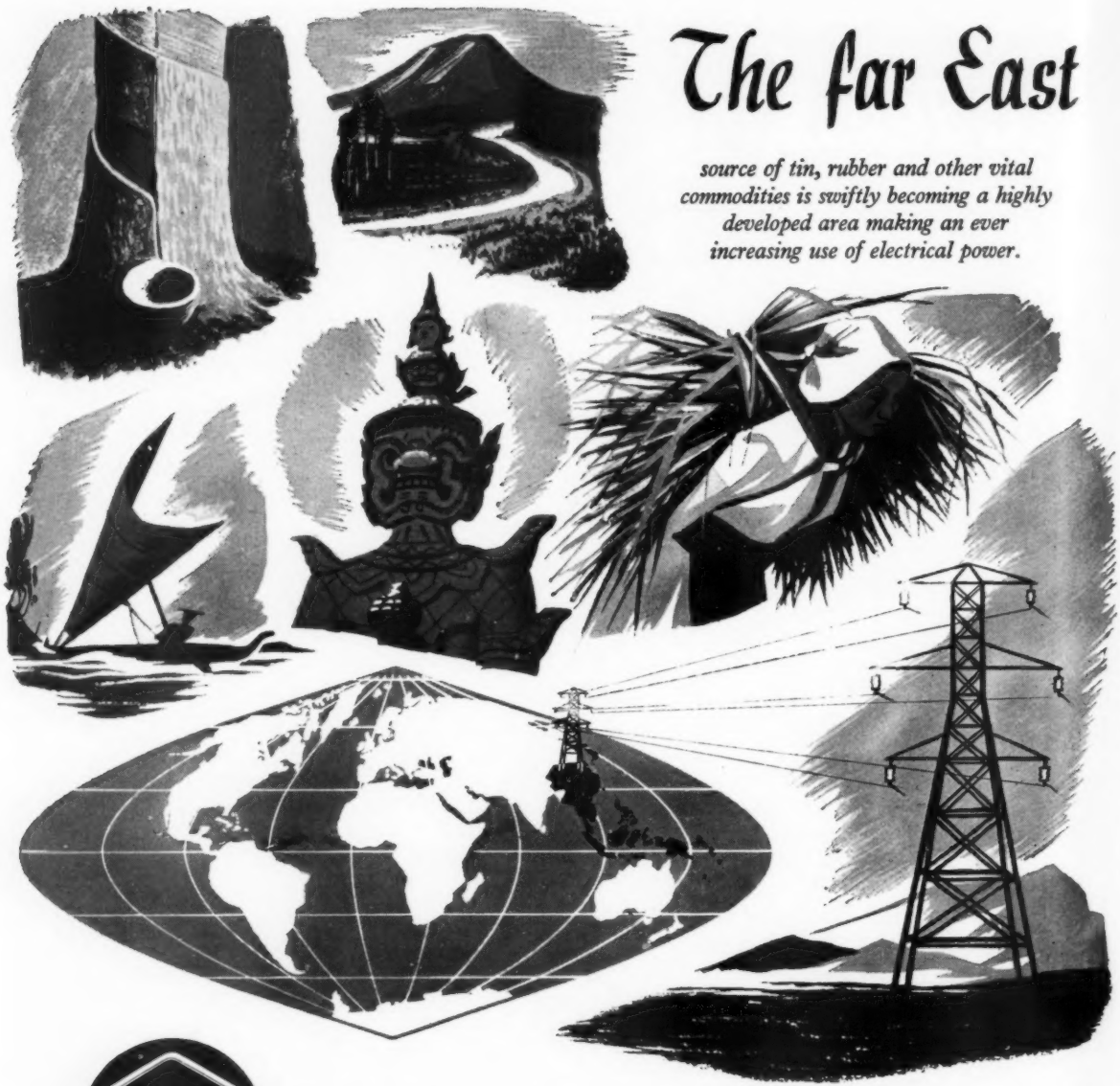


Fig. 4 German Letters Patent 289667 of 28th November 1913, Turbine Runner fitted with adjustable Blades.



J.M.Voith G.m.b.H., Engineering Works, Heidenheim (Brenz), Germany

have supplied or on order a total of 515 Kaplan Turbines with an aggregate output of 2,500,000 BHP.



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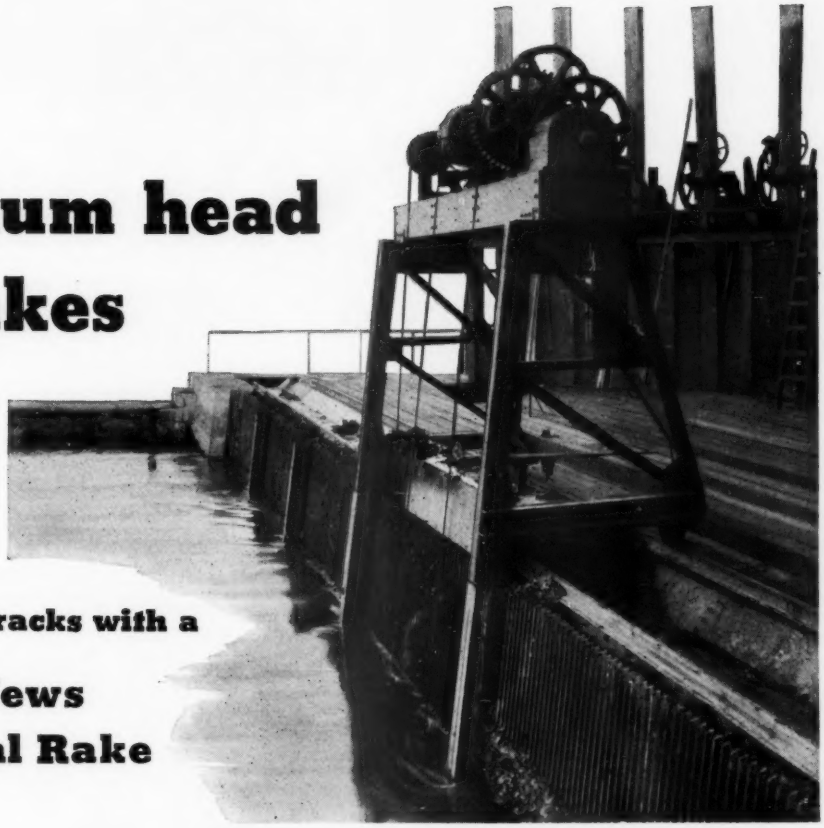

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Newport News Mechanical Rake

Keeping racks clean is essential wherever a few inches of head loss can reduce output of the wheels.

One company calculated the capitalized value of each inch of head gained at its plant as $6,000. Measured in terms of the value of additional power output, a Newport News rack rake installed at this plant is paying for itself over and over again the year 'round.

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Under ordinary conditions, one man per shift can, with a Newport News Mechanical Rack Rake, keep the racks clean for a dozen bays.

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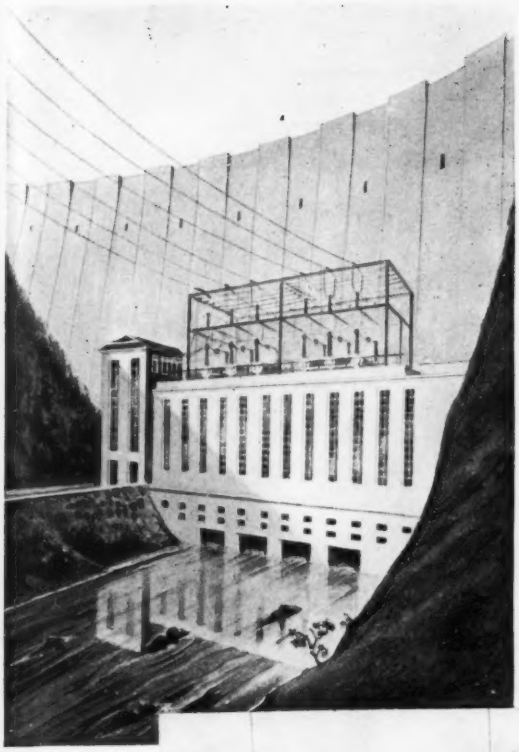
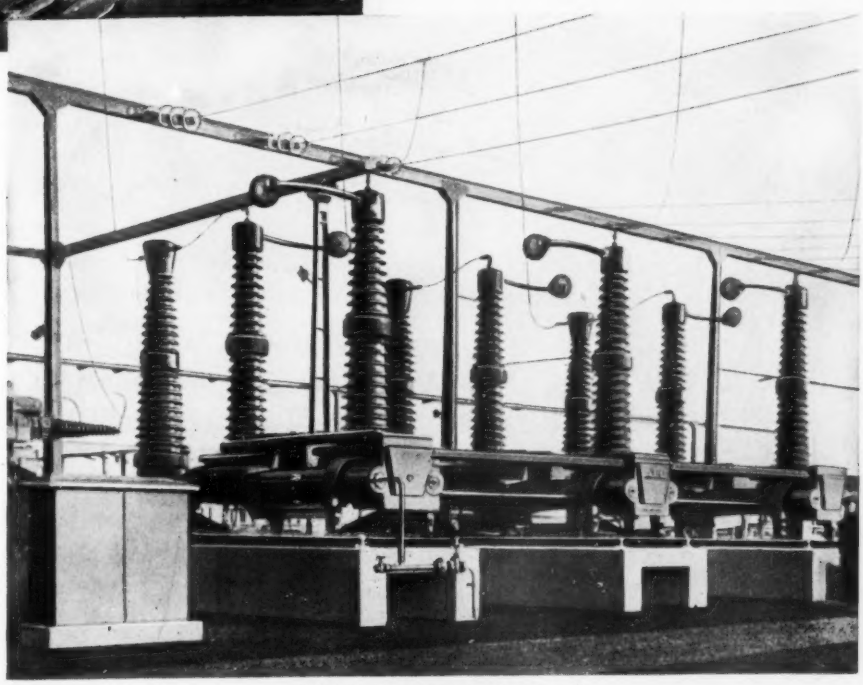


AEG

Outdoor and Indoor High Tension Switchgear for Hydro-Electric Power



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5312

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Berlin-Grunewald — Export Department — Frankfurt a.M.

water turbine engineers

OIL PRESSURE GOVERNORS SLUICE-GATES AND COMPLETE HYDRO-ELECTRIC INSTALLATIONS

View of interior of power house over two low head Armfield Francis turbines. Each turbine drives a 45 KW alternator and is independently governed.
The sets operate in parallel with each other and with a further Hydro-Electric and Diesel installation some two miles downstream.
This installation was recently completed to the order of A. F. Wallace, Esq., of Candacraig.
Consultants—Messrs. Griffin Smith & Partners Ltd.

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THE ARMFIELD HYDRAULIC ENGINEERING CO. LTD., RINGWOOD, HAMPSHIRE, ENGLAND

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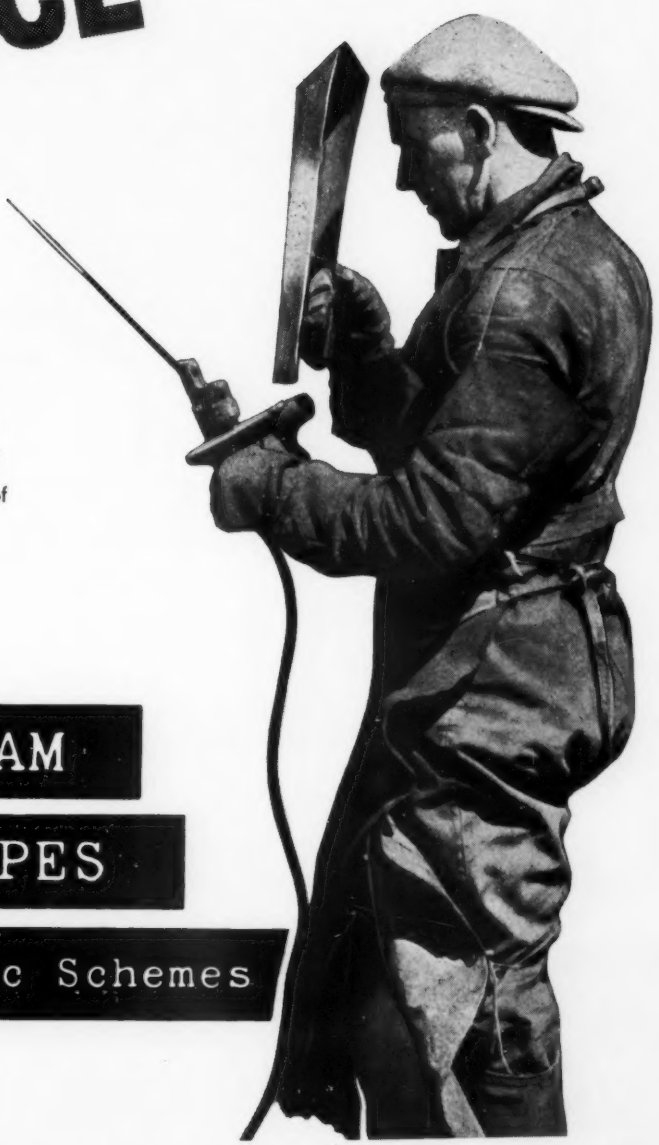
For Hydro-Electric Installations South Durham service is complete. It embraces the design, manufacture, installation and final test of all piping supplied. The advice and experience of our Technical Staff and drawing office are readily available for the assistance of engineers engaged in the planning of Hydro-Electric projects.



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South Durham Steel & Iron Co., Ltd., (incorporating Cargo Fleet Iron Co., Ltd.) *Central Selling Office: Cargo Fleet Ironworks, Middlesbrough*

Leffel

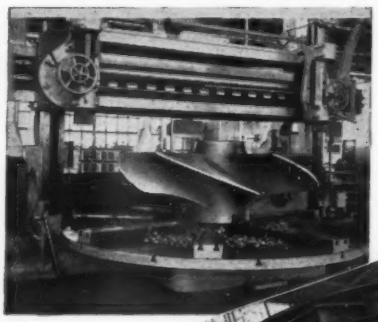
HYDRAULIC TURBINE

increases

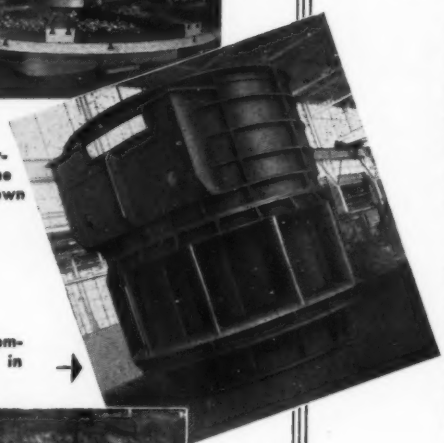
power output at

WILBUR DAM

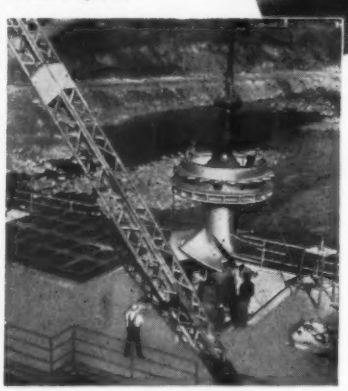
of the Tennessee Valley Authority



Cast steel propeller-type runner for the Wilbur turbine, shown on boring mill.



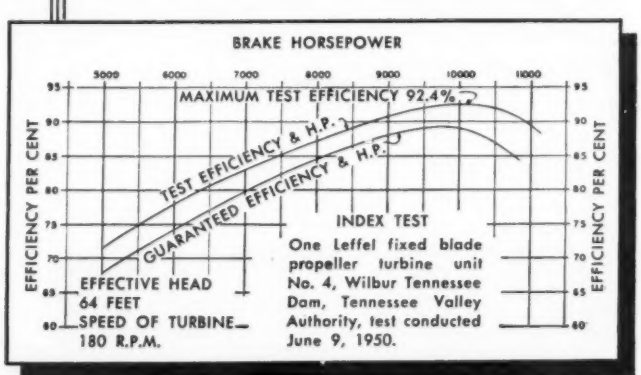
Wilbur turbine, completely assembled in the Leffel plant.



Lifting the combined runner, shaft and coverplate during the field installation.

The Wilbur power project of the TVA is another instance where a Leffel hydraulic turbine was used for the expansion of existing power facilities. For the Wilbur installation a Leffel vertical propeller-type hydraulic turbine was used — maximum rated at 11,500 HP, under 67 feet net head, speed 180 RPM.

The Wilbur project demonstrates once again that the long-range economy and dependability of Leffel turbines make a valuable asset for any expansion or rehabilitation. Our facilities are backed by 91 years of reliable service to the water power industry. Why not let us help you with your project, whether it be expansion, rehabilitation or a new installation?



Field Test Results

1082

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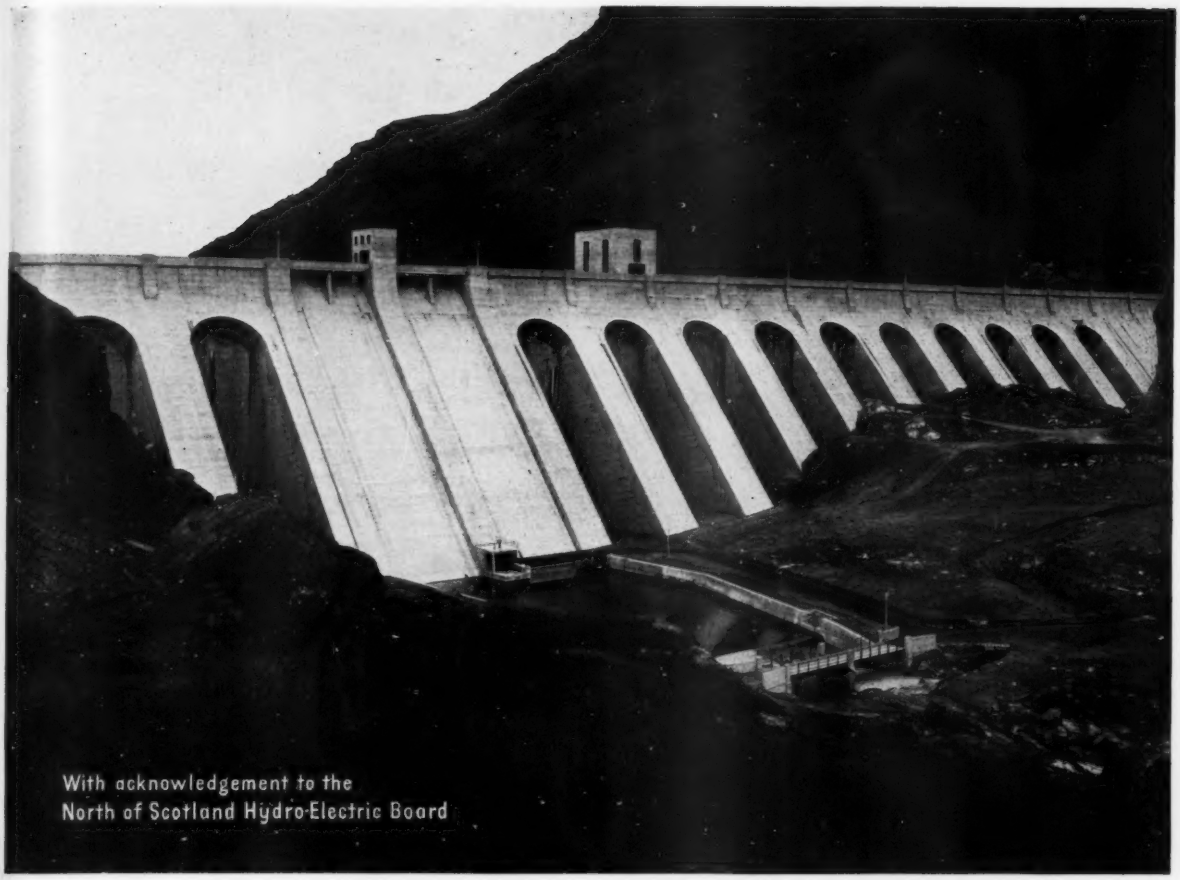

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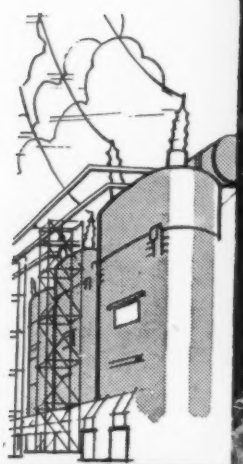

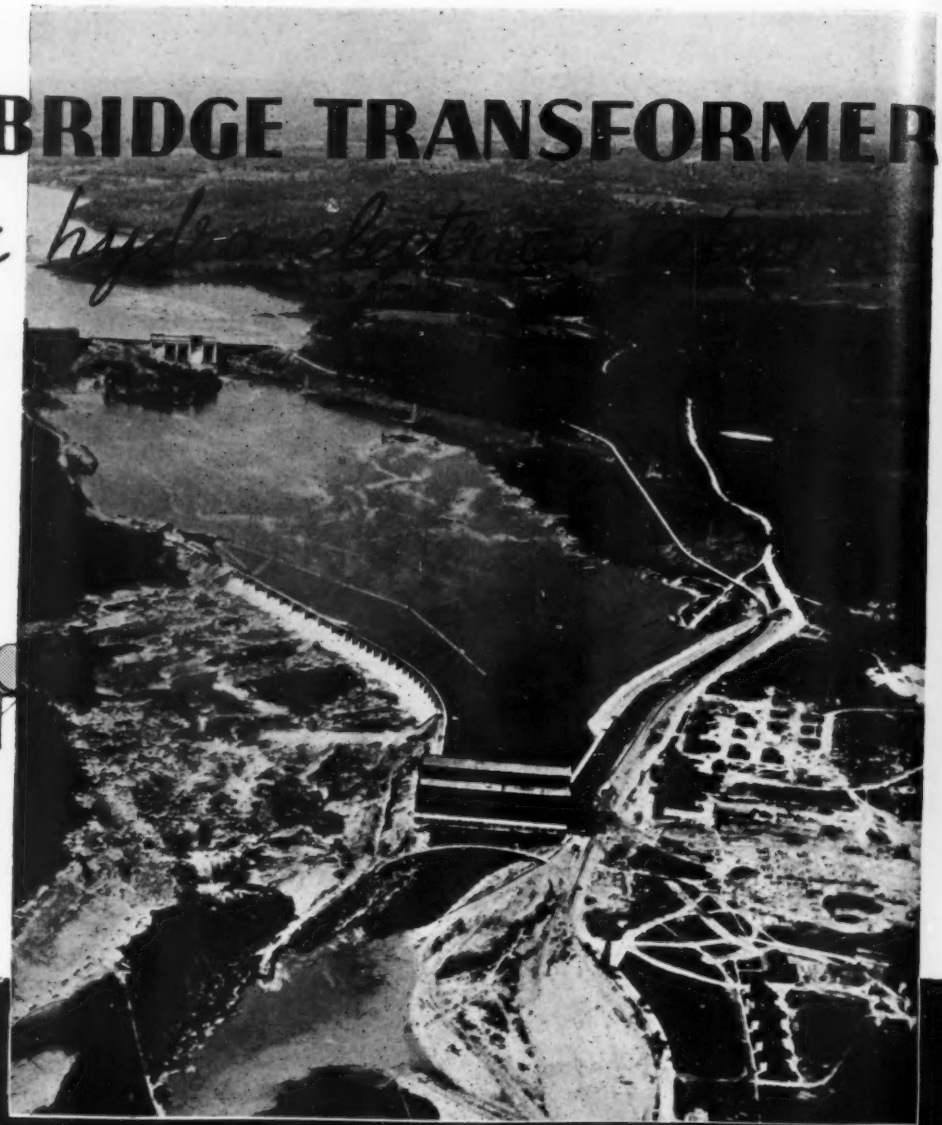

THE Hackbridge & Hewittic Electric Co. Ltd., has a long and extensive experience in the manufacture of water cooled and other types of **TRANSFORMERS**, up to the largest sizes, for hydro-electric power distribution. **HACKBRIDGE TRANSFORMERS** have established an unrivalled reputation for *reliable service* in world-wide hydro-electric installations, with operating conditions ranging from the tropical heat of East Africa to the extreme cold of Northern Canada.

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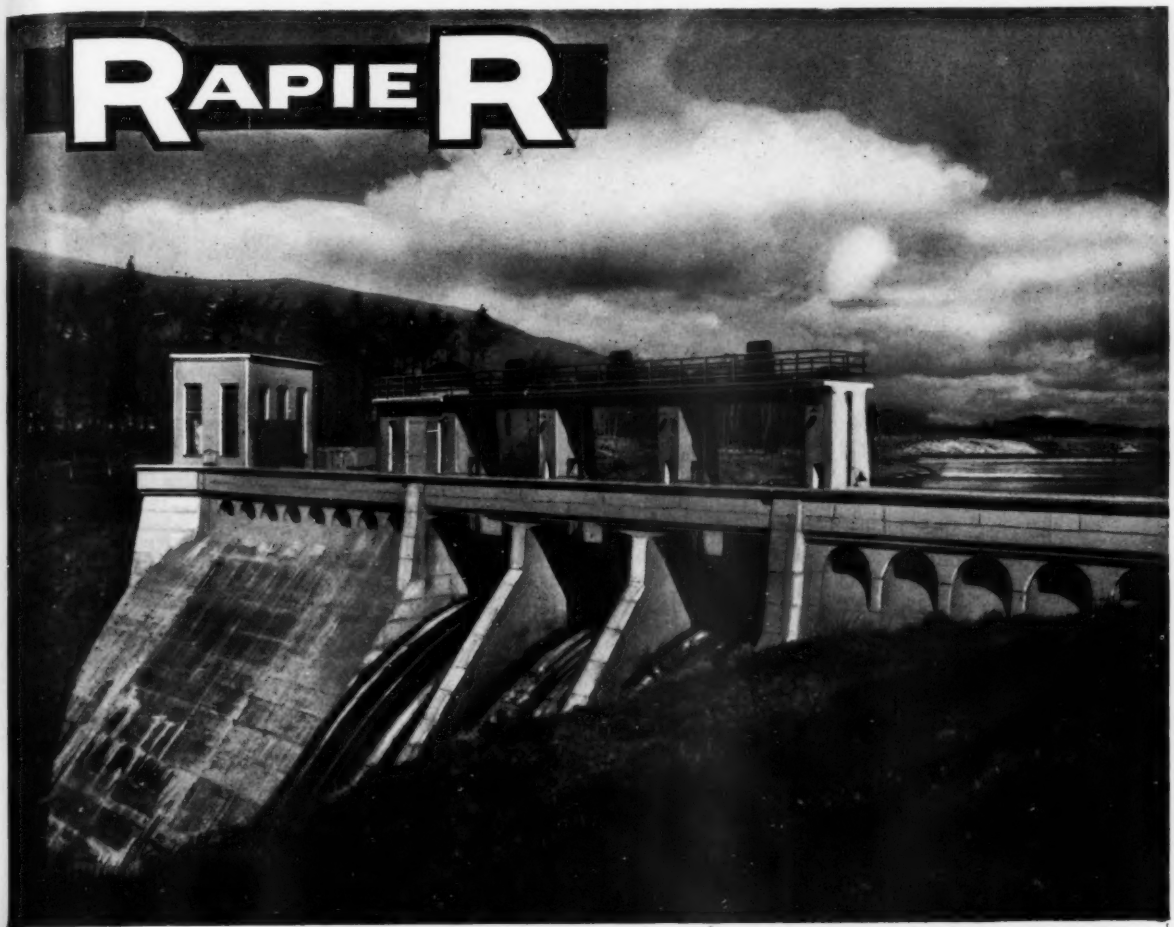

RAPIER

[A typical installation of RapieR Gates for Spillway at the dam for Pollaphuca Power Station on the River Liffey, Eire

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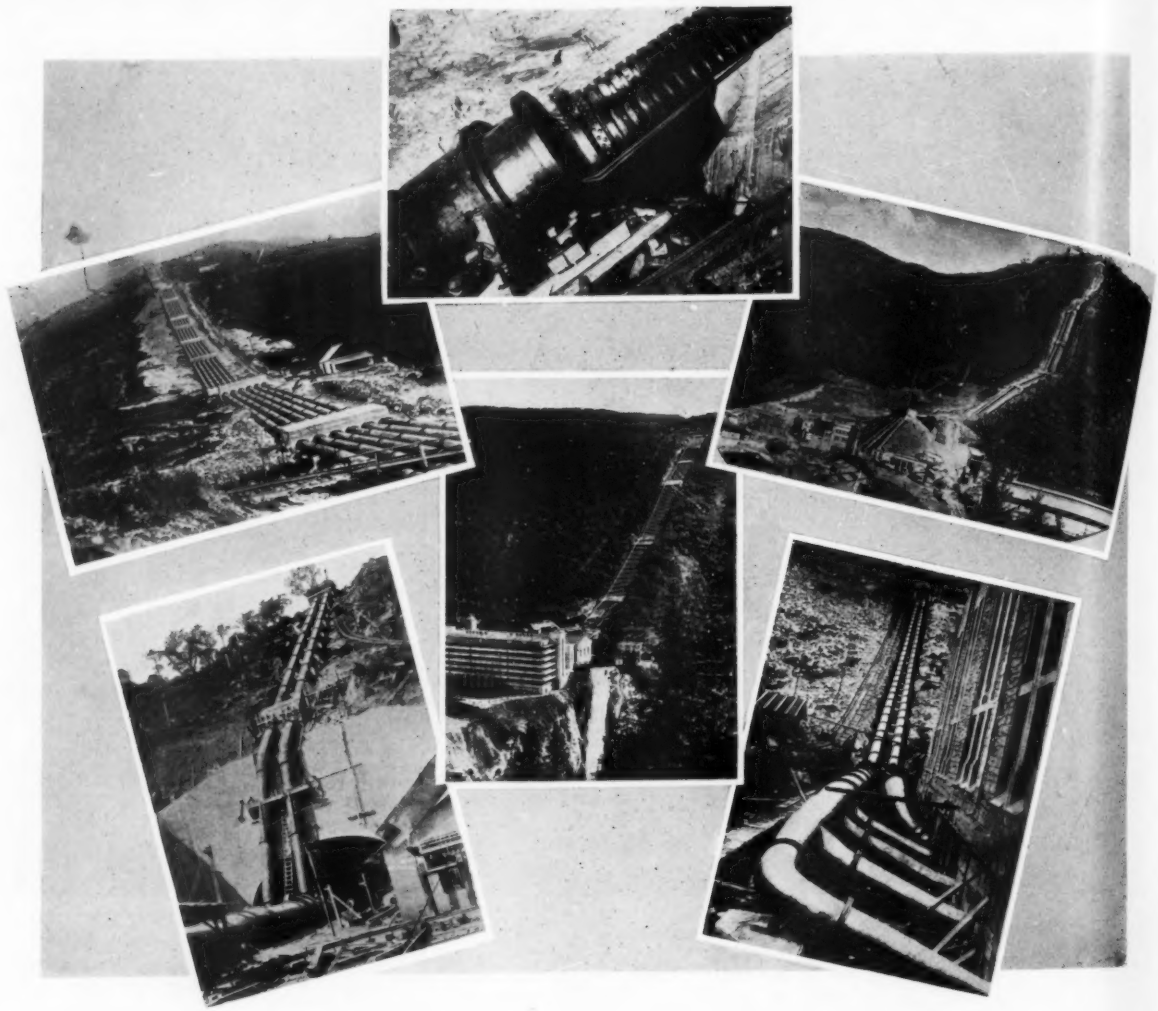

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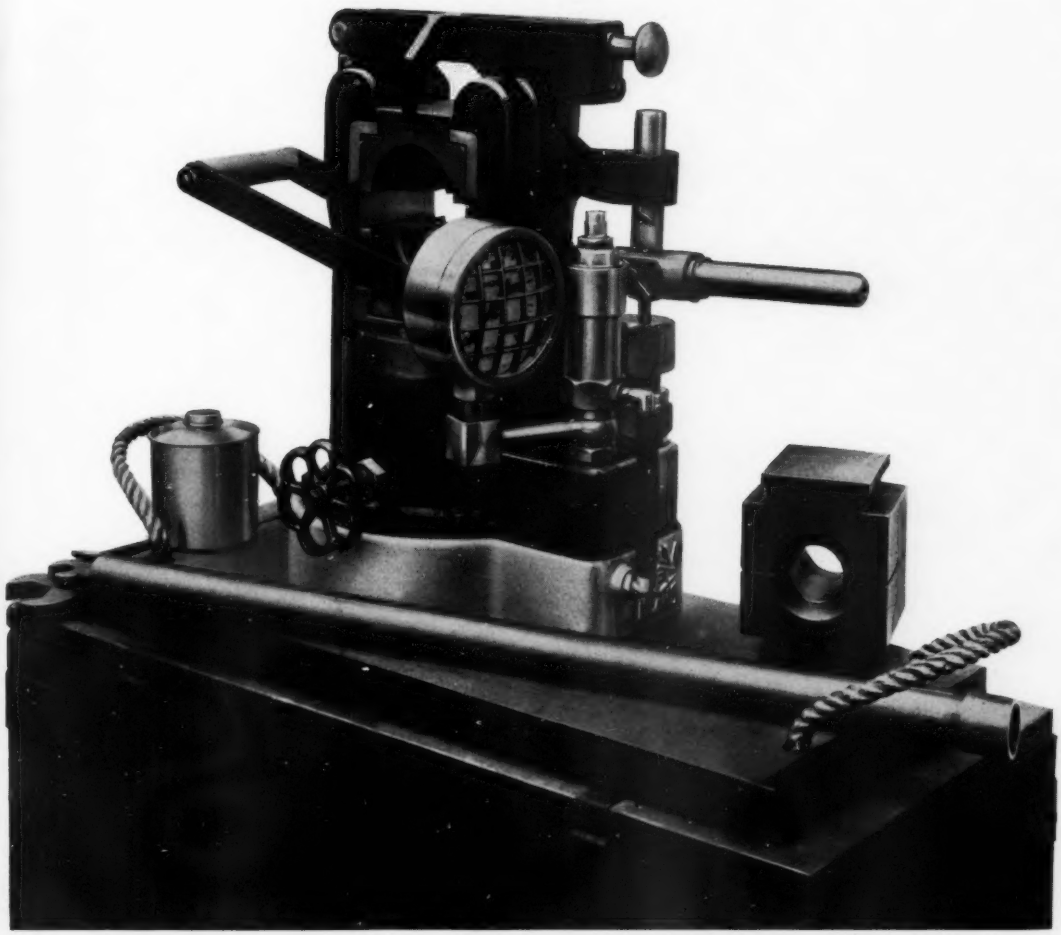

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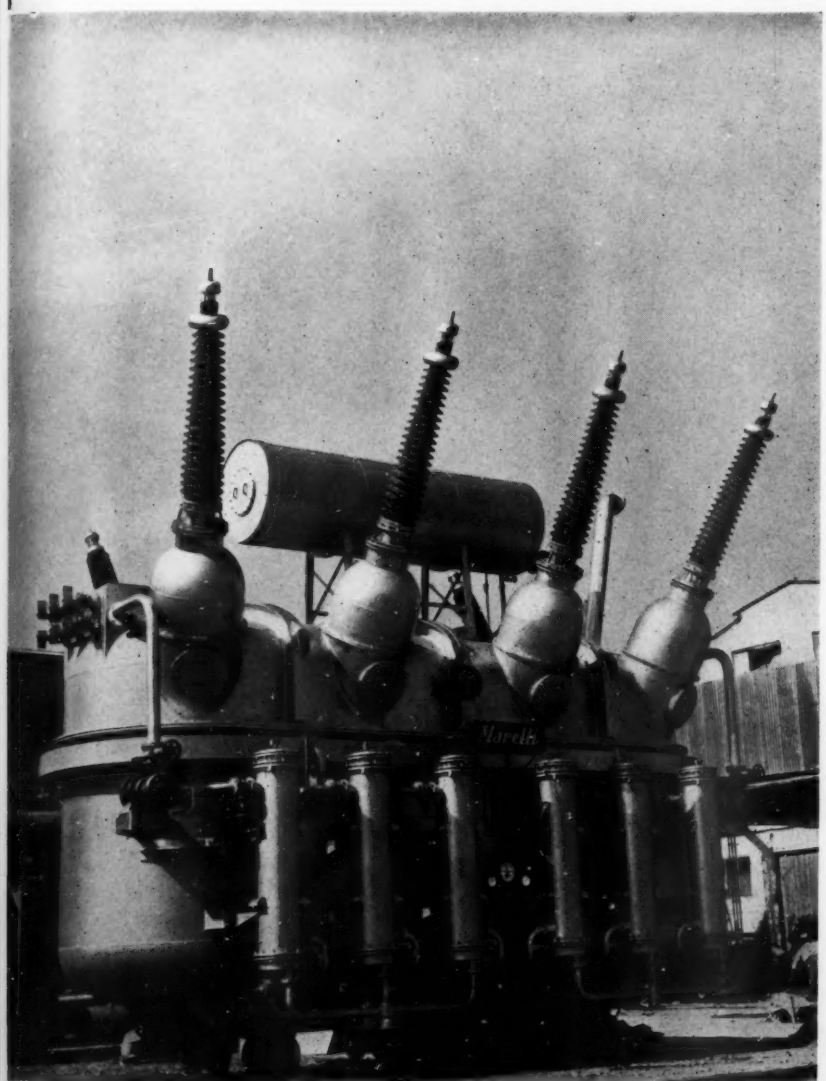

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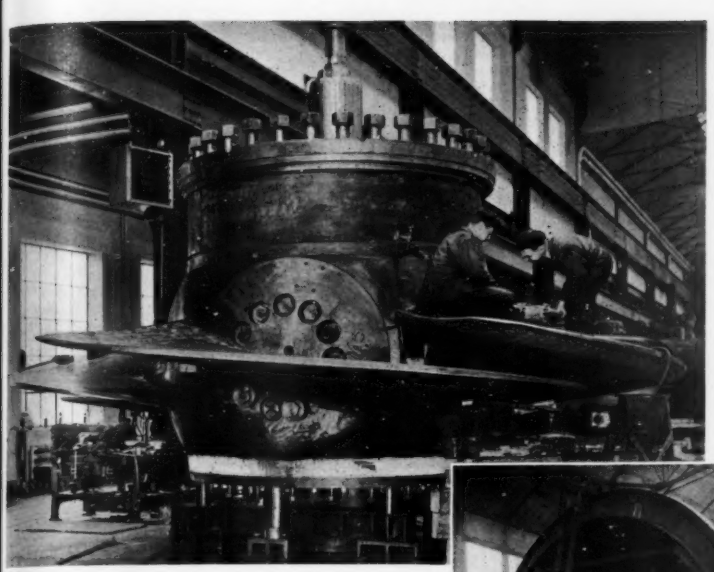
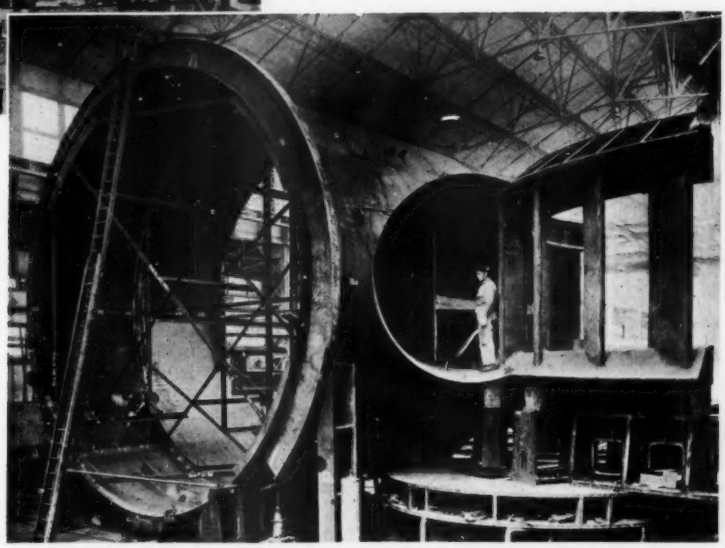


A Kaplan Runner during assembly in our works



Shop assembly of a spiral casing

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on order from KMW

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Normal Head: 88.5 feet

Output: 65,000 H.P.

Speed: 100 r.p.m.

Runner dia.: 19 feet

Weight of each complete runner: 135 tons

Runner blades in stainless steel

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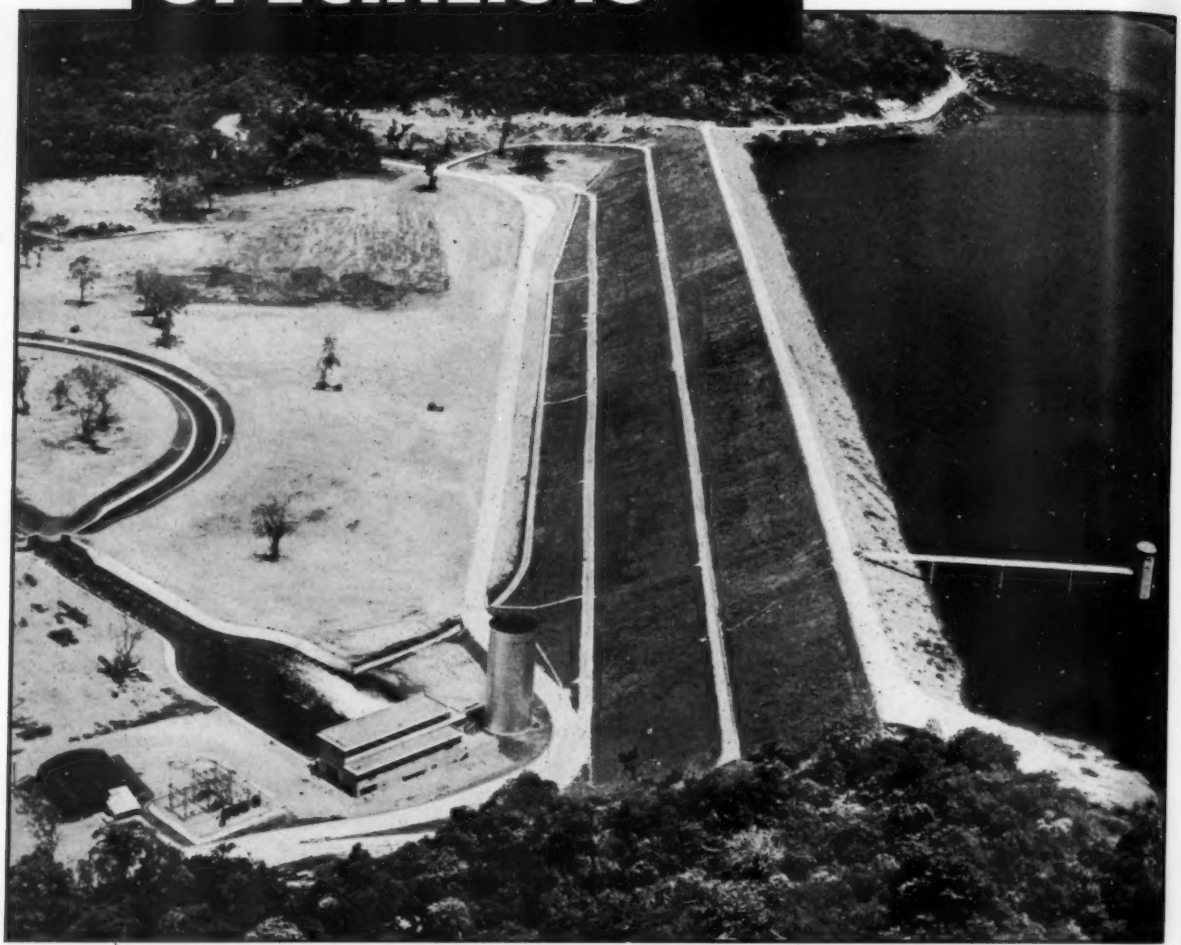

GAL OYA DAM, Ceylon — completed 1952 for hydroelectric power, flood control, irrigation. 3400 ft. long; 125 ft. high.

Harnessing water power has been a speciality of the Morrison-Knudsen organization for more than 40 years. The skill and experience accumulated over these years is your assurance of the efficient planning and competent execution so essential for the successful completion of large-scale water power developments.

Through International Engineering Company, a Morrison-Knudsen subsidiary, this experience is available to you for the design and construction of hydroelectric schemes and irrigation projects in any part of the world.

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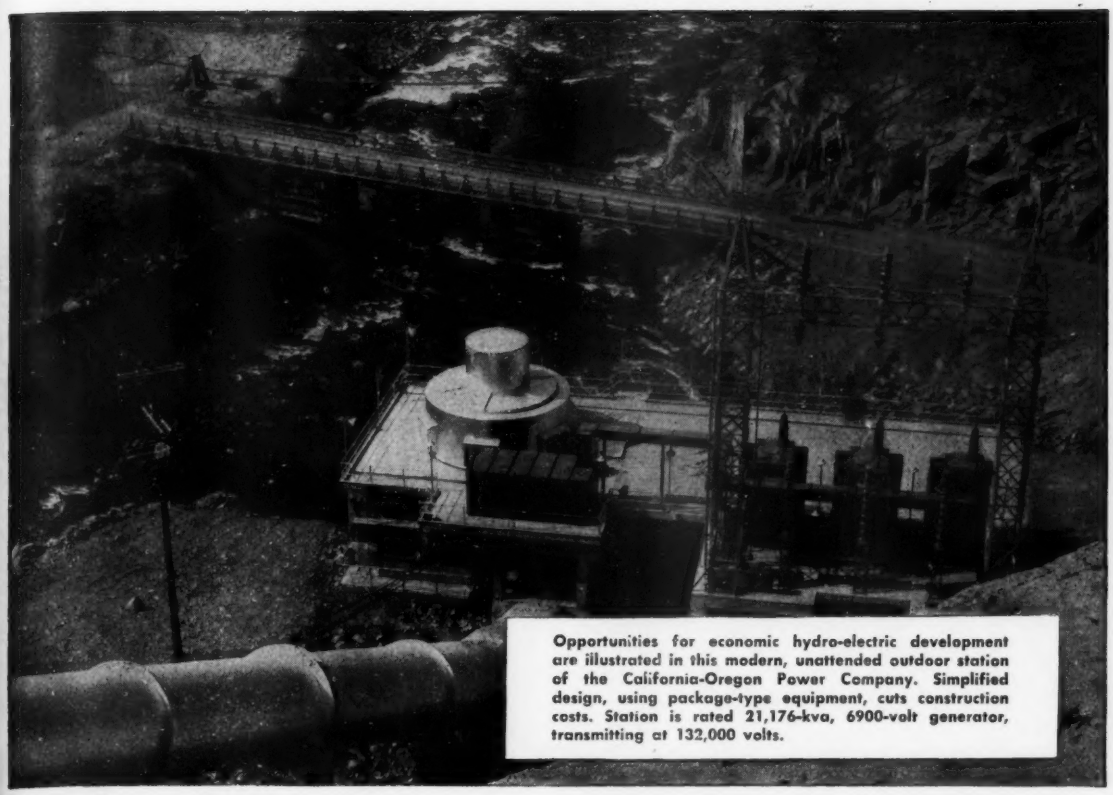

Opportunities for economic hydro-electric development are illustrated in this modern, unattended outdoor station of the California-Oregon Power Company. Simplified design, using package-type equipment, cuts construction costs. Station is rated 21,176-kva, 6900-volt generator, transmitting at 132,000 volts.

Automatic stations spark new interest in development of marginal hydro-electric sites

One of several package-type electrical equipments for hydro-electric stations, this model is being inspected by J. B. McClure, Manager, G-E Power Generation Div. Equipment design is completely co-ordinated, simplifying installation.

With low operating costs and simplified modern construction, small hydro-electric stations can be profitable investments

At a time when larger and larger generating stations tend to hold the spotlight as an obvious answer to growing demands for power, electric utilities are showing marked interest in small, unattended hydro-electric developments.

The reasons may be found in the increased opportunities for economic construction and operation offered through modern, factory-assembled equipments and proved methods of automatic control.

Engineered by General Electric, compact, package-type electrical equipment for hydro-electric stations is readily adaptable to remote control automatic or semi-automatic operation.

Designed around a simple line-up of hydraulic turbine operated generator, metal-clad switchgear, power transformer and outdoor station structure, they can be shipped in a minimum of sub-assemblies to simplify installation and reduce expense. In many cases, advantage can be taken of low cost outdoor station construction.

Water power is one of the great resources of a nation. Modern engineering advances, typified in these dependable, factory-assembled equipments, will speed its development to the maximum possible economic limits. See your G-E representative for more information. Or write: International General Electric Co., Central Station Sales, 570 Lexington Ave., New York 22, N.Y., U.S.A.

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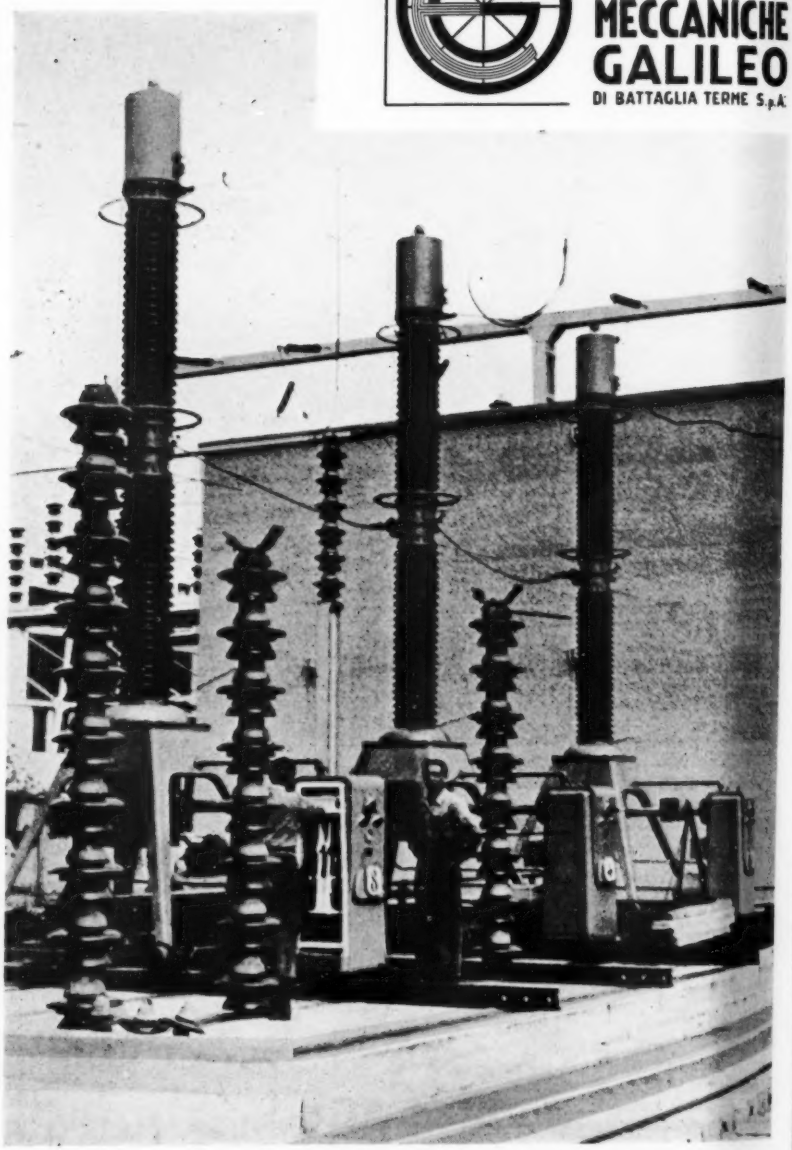

The illustration shows :
Switchgear type OCERD 220 photographed during a test for maximum load, made with favourable results at the test station of Messrs. Eléctricité de France at Fontenay aux Roses (Paris).

Specification of the switchgear :
OCERD 220-225 kV
600A
5000 MVA

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A Further Milestone of Endeavour Towards bringing the Belgian Congo into the Sphere of Civilisation.

"One of the three 15.000 KVA, 333-1/3 r.p.m. vertical alternators supplied to the Société Générale des Forces Hydro-Électriques of Katanga for its Bia Power Station at Koni on the Lufira river.

Power from these alternators is transmitted to the sub-station of the Union Minière du Haut Katanga through a 120.000 v high tension network comprising more than 300 miles of lines. This station has been in regular service since the year 1950".

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complete with four spherical
inlet valves, governors, and
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The third unit has been
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Two Electric Travelling Cranes,
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Operating gear sets for
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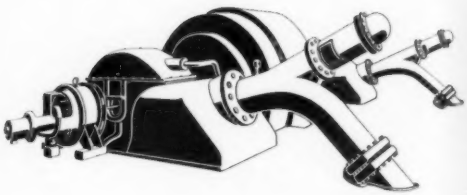
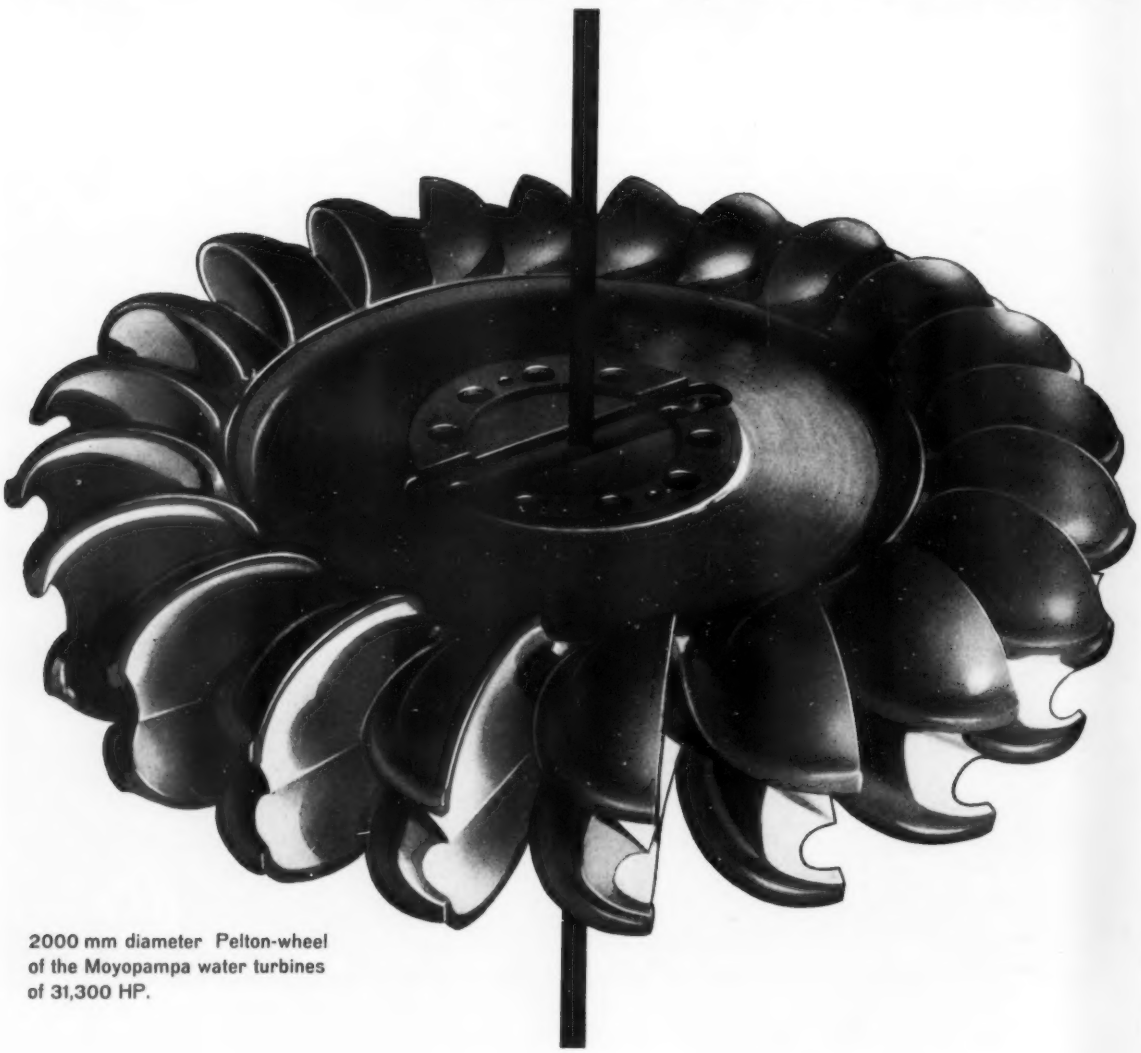
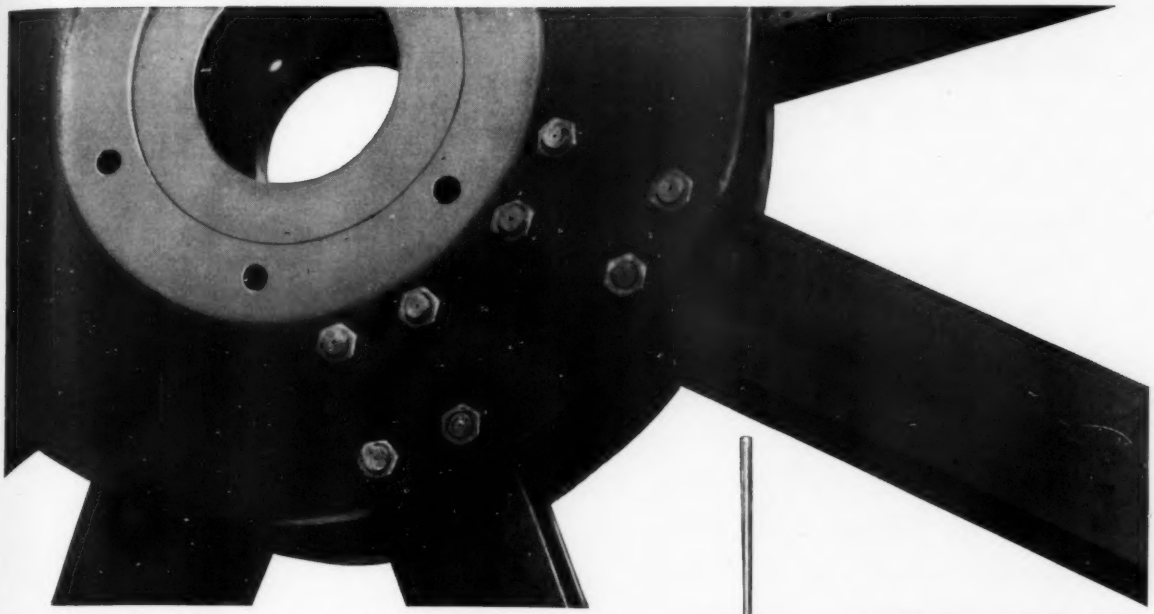
Forebay with scour outlet,
flood gates and intake
sluice gate.



Engineering Works Theodore Bell & Co. Ltd. Kriens-Lucerne (Switzerland)



2000 mm diameter Pelton-wheel
of the Moyopampa water turbines
of 31,300 HP.



The Oerlikon Engineering Company has always attached great importance to its experimental and testing plants. Products are repeatedly checked in the Testing Departments for correct performance and maintenance of guaranteed values. The picture shows the measuring of vibrations on the testing plant for large alternators.

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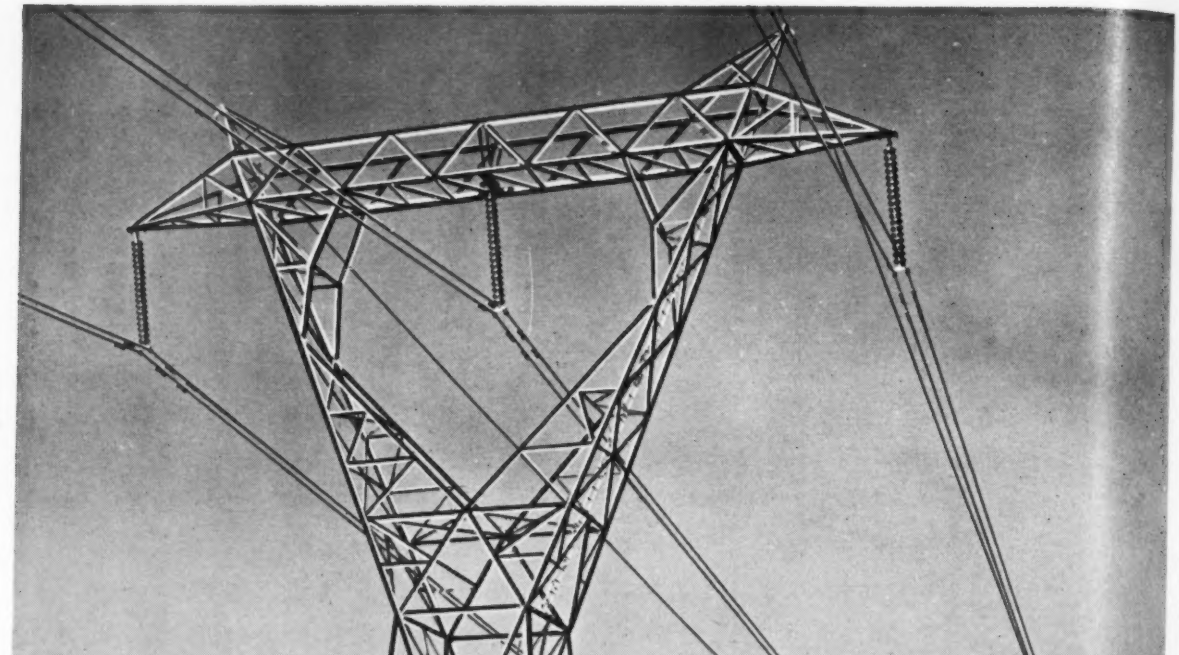
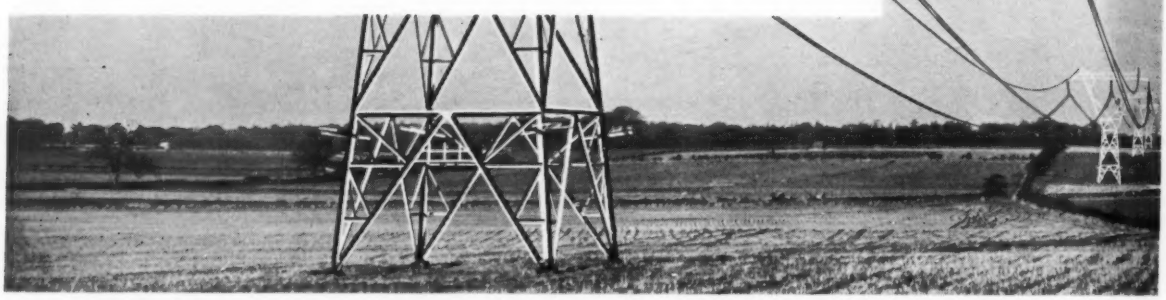


259 MILES OF SUPER-GRID



by the **BICC GROUP**

The first section of the British Electricity Authority's new 275 kV Super-Grid—the 20-mile single circuit length from Staythorpe to Barnby Moor (shown here)—was constructed by the BICC Group. The conductors were supplied by BICC, a special feature being the twin conductor formation introduced for the first time in this country. The towers were designed and supplied by Blaw Knox Ltd.

In addition, the BICC Group have contracts in hand for double circuit sections of the new Super-Grid totalling 239 miles. These are: from Stella (Newcastle) to Thirsk (62 miles); from Staythorpe to Elstree (114 miles); and from Drakelow Power Station (Burton-on-Trent) to Carrington (Manchester) (63 miles).

The BICC Group—incorporating BIC Construction Co. Ltd.—are specialists in steel tower fabrication and the construction of high voltage overhead transmission lines, and undertake work of this nature in all parts of the World.

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Pumped Storage

IT is heartening to find a still small but steadily growing interest in pumped-storage schemes. The British Electricity Authority, in their recently-published Annual Report, state that they have been carrying out investigations at a number of sites in Great Britain, and conclude that "one or more schemes might be developed which would compare favourably, in capital cost and in running cost, with equivalent capacity of new steam power stations . . ." It is significant also that at least one leading turbine manufacturer, in his recent advertising announcements, has been stressing the advantages of the reversible pump turbine.

The basic problem which has always faced the electricity supply engineer is that of storage. Although electricity supply on a commercial scale is now about 75 years old, there has been little indication of any practicable solution to the storage problem. The accumulator, efficient though it may be for its own limited purposes, has never become a serious contender for the storage of the output of large generating stations at off-peak times. In this connection, some interesting experiments with a wind-power generating scheme were recently to be seen at an exhibition held near London, with the object of storing the energy produced by variable wind flow so that a constant output might be assured. Here the conception was to use wind-generated power for electrolysing water to form hydrogen and oxygen, this being carried out on a model plant. While in this particular case the oxygen was allowed to escape, and the hydrogen stored for use in a gas engine driving a generator, it is easy to conceive of circumstances in which both gases could be used for power generation. It may well be the case that this method has useful practicable applications on a small scale, but it is unlikely that the losses in this conversion and reconversion operation could ever be reduced to an acceptable economic figure for large-scale plants. The storage of energy by thermal processes was also demonstrated in various forms; but as storage experiments can only be of use if they assist the power-station engineer in his task of meeting the peaks in the load curve of the whole of any large network, no method which involves extensive conversion processes, whether thermal or not, is likely to succeed. The capital charges on the additional plant needed, and the cost of the losses, might substantially exceed the capital expenditure now found to be necessary on providing normal generating plant to meet the peak load.

There remains to be considered one further line of research which may have important possibilities in the future. It relates to the fuel cell. The advantage here is that the complicated and wasteful processes of electro-magnetic power generation from a solid-fuel source are bypassed, and the chemical energy in the fuel translated directly into electrical energy without the interposition of boilers, rotating machinery and the copper, iron, and frictional losses inseparable from conventional methods of power generation. Nevertheless, even if the fuel cell be developed so that it plays an important part in power production, it will still rely on the availability of fuel, and on the willingness of future generations to bring it to the surface; and moreover its electrical output is in the form of low-voltage direct current, and thus inverting and transformation equipment would be necessary.

The coming of nuclear power generation will not of itself affect the storage problem, since as far as can be foreseen the nuclear reactor will take the place only of the boiler house, and does not offer any particular advantage when considered solely from the point of view of obviating the provision of plant which only performs a useful service at peak times.

Thus it appears that the hydro-electric engineer alone holds the key to the solution (in certain cases, at any rate) of the problem of storing electrical energy. If this is true, not only hydro-electric plants but thermal power stations as well can operate at efficiencies much greater than the figures at present recorded, and whole groups of power stations can be designed on lines considerably different from those which now dictate the size and location of the various power generating units.

Of course, the pumped-storage solution can only be applied where the topography of the site allows for

a suitable reservoir. The transmission losses which might be incurred by sending power from underloaded distant stations during the night hours to pump water back from the low-level reservoir to the high-level reservoir have also to be taken into account. Here again the location of the proposed pumped-storage plant is a determining factor in assessing its ability to bring economic relief to the system as a whole. The Schluchsee plant, which is the largest pumped-storage scheme in Europe, is connected to thermal and run-of-river hydro-electric plants on the Rhine, and is also linked in with the Austrian and Swiss networks. It has been of very great economic advantage to the Rhenische Westphalische Elektricitwerke. The three Schluchsee stations, working in series, have a yearly output of 600 million kWh, and of this total about half comes from the normal operation through water drained from the watershed and half is generated from the pumping of tailwater from the River Rhine back to the main reservoir. The thermal plants can be operated more efficiently by being given a suitable proportion of the off-peak pumping load. The pumps in the first station take 22 MW and in the second station 32 MW, while the third, at Waldshut, needs 18 MW. These are not large figures when compared with even the off-peak loads on large networks, but they are large enough to prove the principle that pumped storage can absorb appreciable amounts of power, whether from lightly loaded hydro stations or from thermal plants, and can redeliver it when it is most needed.

There is every likelihood that there will be many more pumped-storage schemes installed in various parts of the world in the next decade. It may well be the case, in spite of more spectacular advances in electrical power techniques, that these pumps, in quietly performing their nightly functions, will form one of the greatest contributions to the security and economy of electricity supply that mankind has yet seen.

World Power Conference Brazil Meeting —Further Details

FURTHER to our note last month we are now able to give some particulars of the tours which the Brazilian National Committee is organising for the second week of the Conference. Two tours are being arranged, visiting the same places but in the reverse order. Participants in these tours will be able to visit São Paulo (which will be in course of celebrating the fourth centenary of its foundation) and to see there hydro-electric installations of about 600,000 kW and a new 200,000 kW thermal station; the Paulo-Afonso Falls, where there is a new underground power station of 120,000 kW; Santa Cecilia water diversion and the Ribeirao das Lages installations; the Paraíba-Piraí diversion, recently fully described in WATER POWER; the "Companhia Siderúrgica Nacional" (a government-operated ironworks); petroleum installations near Salvador, the capital of the Province of Bahia; and hydro and thermal plants in the region of Rio de Janeiro.

A strong British delegation, headed by Sir Vincent de Ferranti, will participate in the Conference, and will contribute 11 papers to the proceedings. One of particular interest to our readers will be "Integration of Hydro and Thermal Electric Power in Great Britain," by J. D. Peattie and A. A. Fulton, and those who are following the potentialities of wind power will study a paper "Economic Aspects of the Utilisation of Wind Power Plants" by E. W. Golding.

St. Lawrence U.S. Order Issued

PRESIDENT EISENHOWER issued an executive order on November 5 designating the New York Power Authority as the official United States participant in the St. Lawrence power development at International Rapids. The order authorises the establishment of a United States section of the St. Lawrence River Joint Board of Engineers, and will consist of the Secretary of the Army and the Chairman of the Federal Power Commission. According to Mr. Hagerty, the White House Press Secretary, this completes the executive action needed for American participation in the project.

Expansion in Turkey

ALTHOUGH Turkey has a large trade deficit with Great Britain, there are signs of an improvement in its economic position and further legislation may result in a large inflow of foreign investment funds. Considerable expansion is taking place in electricity supply and great efforts are being made to extend the use of electric light and power. In addition to the doubling of output at Catalgzi, plant for which is being supplied by a British firm, there are some 13 hydro-electric projects under construction, including the Seyhan barrage which will have an annual output of 284 million units. The present gross plant capacity of 800 MW will be greatly augmented when these and other hydro-electric schemes are brought into operation.

McCormick Dam Opened

THE fifteen million dollar McCormick dam at Manicouagan River has been officially opened by the Premier of Quebec. The project was designed primarily to supply power for the Chicago Tribune's newsprint mills on the St. Lawrence River, but current will also be available for any new industries in the area.

Contracts for Breadalbane Scheme

THE North of Scotland Hydro-Electric Board have placed the first of the main contracts for their Breadalbane hydro-electric scheme. This project is estimated to produce an average annual output of 304 million KWh and involves the headwaters and tributaries of the Rivers Lyon, Lochay, Dochart, Lednock and Almond, the Monachyle Burn and Loch Earn. James Miller & Partners, civil engineering contractors, Edinburgh, have been awarded the contract to build the Lubreoch dam in Glen Lyon and to construct permanent access roads in Glen Lochay and Glen Lyon. A start has already been made on the roads, and bridges in both glens are being strengthened. Edmund Nuttall Sons & Company (London) Limited, who were the contractors for the main tunnel of the Loch Sloy scheme, are to build the Stronuich dam in Glen Lyon and drive the five mile long main tunnel from the dam to the generating station in Glen Lochay. The value of each of these

contracts is over £2,000,000. On the St. Fillans section of the scheme, Messrs. Struthers & Denny, Edinburgh, are carrying out improvements to the Comrie-Glen Lednock road to provide access to the dam which will be built in that glen.

Work on two small hydro-electric schemes in Argyll has also started recently. They are the Kilmelfort scheme, near Oban, which will produce about 9 million kWh annually, and the Allt-na-Lairige scheme which will use the headwaters of the Allt-na-Lairige and some other tributaries of the River Fyne for the production of about 17 million kWh of electricity per annum. The civil engineering contractors for the Kilmelfort scheme are R. J. MacLeod, Limited, Glasgow, for the River Oude works, and Wm. Arnott McLeod & Co., Ltd., Edinburgh, for the Loch Tralaig dam and other works. The civil engineering contractors for the Allt-na-Lairige scheme are Marples Ridgway & Co., Ltd., London.

Difficulties in New Zealand

IT would seem that the Roxburgh hydro-electric scheme in New Zealand has become a major issue between the political parties, and Government spokesmen have been put to the necessity to defend the contractors from severe Oppositional criticism. The general trend of this criticism is that progress has been slow and that money has been unnecessarily wasted in flying out unskilled workmen from Great Britain. These charges of tardy progress and extravagant finance have been strenuously denied by Mr. Holland, the Prime Minister, and by Mr. Goosman, Minister of Works, but the situation is far from happy, as will always be the case when a purely economic issue becomes a political battleground. Some of the difficulties would appear to lie with the dual control system which has been instituted, in which the Ministry of Works has engaged what is considered to be an excessive number of inspectors to check the work—a factor which has hampered the contractors and is said to have added much to the expense.

Vancouver Island Progress

A FURTHER unit has now been put into commission at the John Hart plant which the British Columbia Power Commission are erecting on the Campbell river, Vancouver Island. A third and final set is expected to be brought into operation before the end of the year, bringing the total capacity of the station up to 168,000 h.p. This station was planned for three-stage development, each stage being represented by a pipeline and surge tank serving twin 28,000 h.p. units. The new 132 kV transmission line from the station to Duncan Bay is also expected to be completed by the end of the year.

Control of Snowy Mountains Scheme

NEGOTIATIONS are in progress between the Governments of the Commonwealth of Australia, New South Wales and Victoria to give the two State Governments a measure of control over the Snowy Mountains development. One of the main reasons for the change, which has already been agreed in principle, is the great increase in costs since the scheme was first approved as a defence measure in 1949, and the New South Wales and Victoria Governments are anxious to keep a check on expenditure so that the ultimate cost of power shall be reasonable. The Victoria Government also feels that its Kiewa scheme is being starved to provide funds for Snowy Mountains.

The Commonwealth Government does not consider that to be the case, and expects that power will be available at about two-thirds the cost of thermal power, but, for its part, wishes to conclude firm agreements with the two States for operating the development as successive stages come into commission.

Basutoland Hydro Project

IN the course of an address to an agricultural conference in Natal recently, Sir John le Rougetel, United Kingdom High Commissioner, referred to a project for erecting a dam at Seforong to impound the waters of the Orange and Senquanyane rivers and so supply Basutoland with hydro power and irrigation water. At the point selected for the dam site the river has cut a relatively narrow gorge 500 ft. deep, through a basalt reef, a circumstance which greatly assists the construction of a reservoir. This would be 90 miles long and would take about eight years to fill. The Orange River is by far the largest in South Africa, but for lack of storage less than 5 per cent. of the run-off is at present utilised. A dam such as is envisaged would not only enable a substantial block of hydro-electric power to be generated but would also serve to regulate the flow of the Orange and provide irrigation water on an annual basis. A pilot agricultural project and experimental station are being set up with a view to providing data on farm mechanisation, fruit drying, meat canning and other power-consuming industries.

Yarmouk River Scheme Held Up

ISRAEL has consented to suspend work on the hydro-electric scheme at Magarin on the Yarmouk River pending consideration by the Security Council of the United Nations. The Yarmouk River forms part of the frontier between Israel and Syria, and although Syrian consent in principle was obtained in 1952, Syria objects to the scheme as now being carried out on the ground that some of the waters to which she lays claim will be diverted from her territory.

Mr. Eric Johnston, President Eisenhower's personal envoy, has been consulting with the Israeli Government with a view to obtaining their agreement to abandon the Yarmouk scheme in favour of the United Nations Plan, prepared by engineers of the Tennessee Valley Authority, to develop both the Jordan and the Yarmouk to provide irrigation and power for the joint benefit of Israel, Syria and Jordan. Latest reports indicate that agreement is not forthcoming.

Hydro Scheme for Donegal

WORK on the Clady River (Co. Donegal) hydro-electric scheme of the Electricity Supply Board of Ireland is expected to commence early in 1954. It is planned that the main dam will raise lakes Upper and Lower Nacung and Dunleavy by about 12 ft. There will be a 1¼ mile racehead canal which will convey water to the power station near the mouth of Crolly River and thence through a 1,600 ft. penstock to fall 194 ft. to drive the turbine.

Correspondence

Slide Rule for Penstock Calculations

To the Editor of WATER POWER

I have many occasions to determine the plate thickness and weight per foot of a pipe for a given head and have devised a slide rule for this purpose. This rule is a 20 in. Manheim-type rule and a print of the face of the rule is enclosed. [Reproduced at a reduced size herewith.—Ed. W.P.] This print is glued to the slide rule and then cut along the lines A-A and B-B. On the bottom of the slide is the diameter in feet from 35 to 10 ft. and in inches from 120 to 20 in. This scale is divided in this manner because it is the custom in this organisation to dimension pipe diameters in inches up to 119 in. and in feet from 10 ft. on up. Directly above this line is a "Minimum Plate" line. This minimum plate thickness is determined from the equation:

$$t = \frac{9 R^2 \delta}{\sigma \text{ max.}}$$

Where t is the plate thickness in inches.
R is the radius of the pipe in inches.
δ is weight per cubic inch of pipe shell in pounds.
σ is the allowable stress in pounds per square inch.

plus other factors, such as weldability, coating and painting and handling qualities. This minimum plate thickness is a matter of engineering opinion and must be changed to suit conditions. In one case I designed a 22 ft. diameter steel tunnel liner for a penstock out of $\frac{1}{4}$ in. plate. It was a little hard to handle, but it is in operation now and is working out all right. Therefore, the minimum plate thickness I have here may not be the one you would select.

On the top of the slide you will find "Stress" in pounds per square inch. I have shown stresses of 27,000, 18,000, 15,000, 13,500, and 12,150 lb. per sq. in., and more could be added to suit any case.

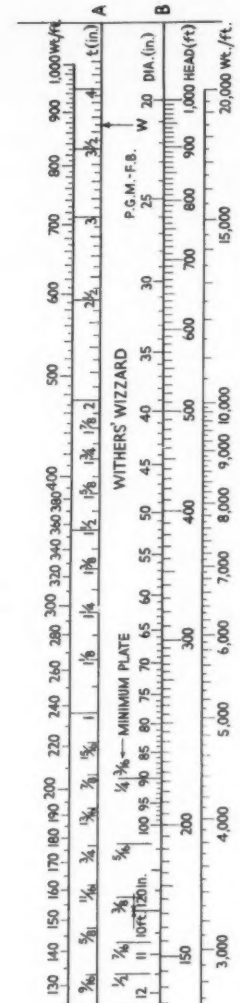
On the stationary part of the rule just above the "Stress" scale you will find "Thickness" in inches, and on the stationary part of the rule just below the diameter in feet scale, is a scale "Head" in feet from 45 to 1,000 ft.

On the extreme outside of the stationary part of the rule, top and bottom, is a folded scale "Weight per foot."

On the slide there are arrows marked W on both ends.

To work the rule. Suppose you wanted to know the weight per foot of a 20 ft. diameter steel pipe, under 250 ft. of head, 13,500 lb. per sq. in. design stress. Place 20 ft. diameter on the slide over the 250 ft. head on the "head" scale; opposite the 13,500 stress on the slide, we find that our closest plate thickness will be 1 in. Now with the aid of the glass indicator place the 20 ft. diameter under the 1 in. plate thickness and then move the glass indicator to the left-hand arrow on the slide. Under this arrow on the bottom scale we will find the weight of about 2,690 lb. per foot of pipe. These weights include 5 per cent. for plate overweight, but nothing for such things as rings, supports, etc.

If we had a 60 in. diameter pipe under 250 ft. head



Scales of the special slide rule devised by Carroll E. Withers for penstock calculations

with a design stress of 13,500 lb. per sq. in. then our plate thickness would be $\frac{1}{4}$ in. Now moving the 60 in. diameter under the $\frac{1}{4}$ in. plate thickness we find the weight per foot on the top of the stationary part of the scale, over the right-hand arrow of 168 lb. per foot.

You can also determine the allowable head for an existing pipe of a given diameter, plate thickness and allowable stress.

CARROLL E. WITHERS.

Denver,
Colorado,
U.S.A.

Book Reviews

The Design of Dams. By A. Bourgin, Engineer in Chief, Department of Bridges and Roads, Government of France, and Professor in the School for Hydraulic Engineers, Grenoble. Translated by Frank F. Fergusson, M.I.C.E., F.G.S., M.A.S.C.E. Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. 344 pp. 262 ff. Price 45s. net.

M. Bourgin's book in French on "Design of Dams" has been very well received by all those concerned with dam design and construction, and the English version of it will certainly have the same success. There are only a few additions to the French version, but the whole contents of the book have been rearranged. The English version is now divided into four parts: Theoretical Background, Gravity Dams, Arch Dams, and Counterfort and Hollow Dams, and this division of the chapters is clearer than the original French version. Few new diagrams and numerical examples have been added to the original version. Most of the examples commented upon are the same as in the French book; p. 181 gives the very interesting examples of the Enchanet dam, a thin arch dam which was not included in the French original.

The main addition is in Chapter XVII, and concerns the "method of inclined arches" by Coyne, for the calculation of so-called "gravity-arch" dams. The mathematical analysis given in the French version was not sufficient for full understanding of the method. In the English version this chapter has now been extended so that the reader can follow Coyne's methods and ideas on this important and controversial point. Similarly the method of cantilever arches and the trial-load method which were briefly summarised in the French version under the name of "method of Stucky" are now dealt with at some length in the English textbook. But at the bottom of page 279 remains the same unfavourable comment that this method appears to have fallen into disfavour because of its complexity and its illusory rigour. This comment should definitely have been mitigated, as there are many proofs that the trial-and-error method yields satisfactory results.

No mention is made of the possibility of using the relaxation method for the calculation of dams. This method has been used for ordinary gravity dams in an attempt to check the results of the theories where simplified assumptions were being introduced. The same method of relaxation has recently been used with complete success for the calculation of gravity-arch dams. There is also no mention whatsoever of the technique of models in plaster or rubber, nor of the extensive research work and measurements on actual dams.

The whole book expresses the French approach to the problem of arch design, which is fairly theoretical with some disregard of the work done in other countries. This is also the impression given by the very short bibliography at the end of the book which does not mention any of the important American, Italian or other publications.

These remarks do not in the least diminish the interest and value of this book. The author, starting from basic principles, builds up his calculation systematically, develops original methods yielding useful formulae. A number of diagrams and charts and several numerical examples will help the reader to translate the theory into numerical calculations.

The French method of approach for arch dams finally leads to the theory of active arches according to which, where a thick arch begins to yield and to be fissured, a thinner arch is formed inside the thicker one with a greater elasticity and a higher strength.

The book, which brings many new points of view and new ideas, is a very useful counterpart to the American approach to the same subject, which has been dealt with in several recent American publications.

Surface Water Supply of Canada (Water Resources Paper No. 105). Water Resources Division, Department of Resources and Development, Ottawa 4, Ontario. Price $3.00, remittance to be in favour of the Receiver General of Canada.

The Water Resources Division announces the publication of Volume 105 of the Water Resources Papers, Surface Water Supply of Canada. This report contains run-off data for the climatic years 1947-48 and 1948-49 for the Arctic and Western Hudson Bay drainage division and for Mississippi drainage in Canada, which cover the whole the Provinces of Manitoba, Saskatchewan, and Alberta, and of the Northwest Territories, as well as some adjoining areas in western Ontario and north-eastern British Columbia. The data presented are the results of the hydrometric operations which were carried out in these drainages during the period October 1, 1947 to September 30, 1949, in large part by the Water Resources Division, although operations were facilitated by active co-operation received from provincial authorities and from a number of private agencies.

This report includes a short description of the organisation and scope of operations, an explanation of the method of tabulation, and 450 pages of stream-flow and water-level data for a number of rivers, streams, and lakes in the above drainage divisions; also six pages of meteorological data pertaining to the operation of evaporation stations. The appendix contains a reference list of hydrometric records for these drainage divisions, a list of available Water Resources Papers, and an index to the current issue.

International Specification for Fuses. The International Electrotechnical Commission has published a specification for fuses for voltages not exceeding 1,000 V for alternating or direct current. The specification relates primarily to industrial fuses, and can be obtained from 39 Route de Malagnou, Geneva, at 5 Sw. fr. plus postage.

Fig. 1. Excavations for the foundations of Cluanie dam

Trief Cement at Glenmoriston Dam

IN their Upper Glenmoriston contract for the North of Scotland Hydro-Electric Board the Mitchell Construction Company have introduced a number of interesting innovations—the use of wet ground blast furnace slag by the Trief process (which is expected to save 20,000 tons of ordinary cement), precast Portland cement facing blocks to save steel or wooden shuttering, and walkie-talkie control of the dumping of cableway cement skips.

The Glenmoriston scheme involves the damming of

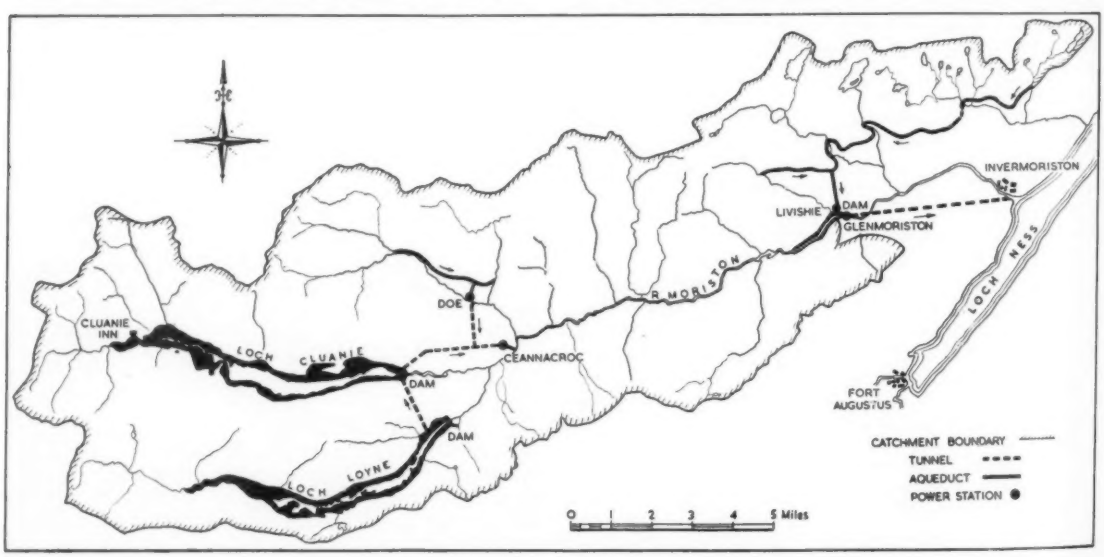


Fig. 2. Locality map of the Glenmoriston scheme

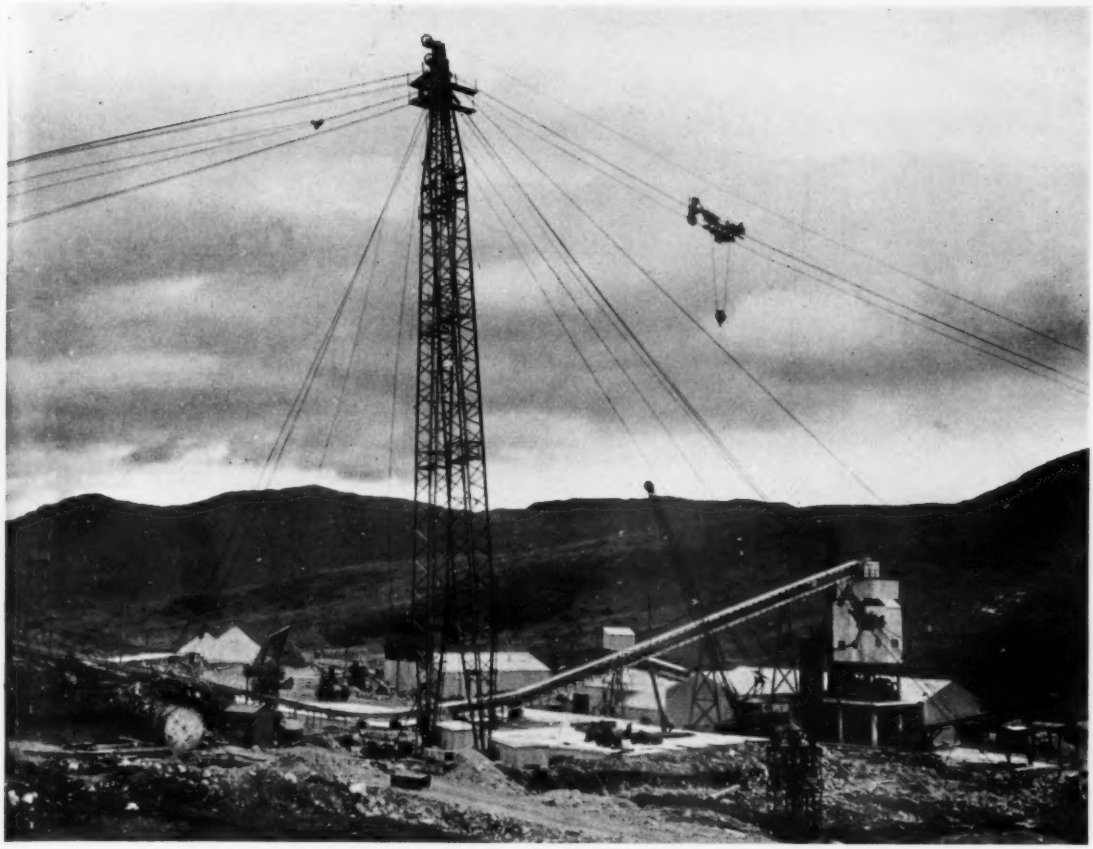


Fig. 3. General view of the preparation plant

two lochs—Cluanie and Loyne—with gravity type dams, the respective dimensions of which are 2,734 by 118 ft. and 1,745 by 64 ft. The faces of both these structures will be built for the first time in Britain of precast concrete blocks. Cluanie (the "a" may be ignored in pronouncing this word) will involve an excavation of 90,000 cu. yards and when complete will contain 250,000 cu. yards of concrete; the corresponding figures for Loyne are 55,000 and 60,000.

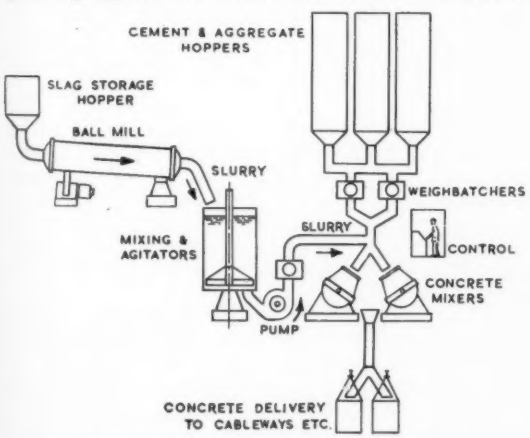


Fig. 4. Flowsheet of the Trief process

One tunnel will bring water from Loch Loyne to Cluanie dam and another will take the combined waters to the power station at Ceannacroc (a Gaelic name meaning "head of the hill"). This, the chief power station, will be underground and of 20,000 kW capacity; there will be other stations at Glendoe and Glenmoriston and the total output should be 65,000 kW or 213 million kWh per annum. Tunnel drivage has been fast—up to 1,000 ft. per week on five faces—and it is expected that Loyne and Ceannacroc tunnels will be completed this year.

Trief Process

The mix used at Cluanie is 70 per cent. slag and 30 per cent. Portland cement to which is added 7 parts of granite aggregate. The attention of the North of Scotland Hydro-Electric Board was attracted to the Trief process by its use by the French Electricity Board at their Bort-les-Orgues dam in 1948. The Board sent a chemist and two engineers to investigate and their reports were sufficiently encouraging for tests to be initiated with Scottish blast-furnace slag at the Royal Technical College, Glasgow. As a consequence the Mitchell Construction Co. Ltd. staked their tender for the Upper Glenmoriston contract on this material and it was accepted, being lower than any tender based on the use of Portland cement alone. The company arranged with Messrs. Colville to supply the slag from their Motherwell

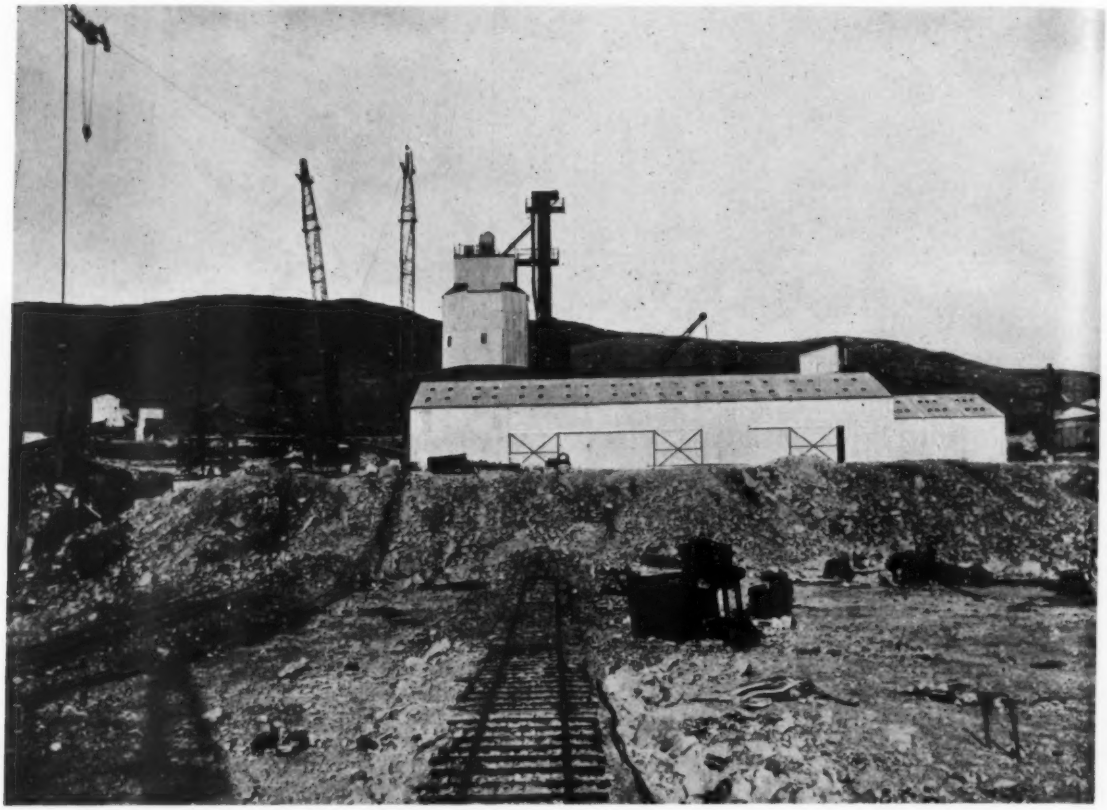


Fig. 5. Another view of the preparation plant showing the cement silo and hoist. The crushing plant is in the background

works and erected the necessary plant at Cluanie.

On 19th October excavation was sufficiently far advanced to begin construction and a distinguished company of engineers and others was invited to witness the inauguration, at which ceremony Mr. C. M. Roberts of Sir William Halcrow and Partners, the consulting civil engineers, gave some interesting details of the factors involved. He said that after seeing the French dam and examining laboratory tests they felt confident that, as far as the bulk of the dam was concerned, the slag mix could meet every provision for the safety of the dam; but as far as the action of acidic peaty water was concerned the ability of this mix to stand up to it had yet to be proved over a period of time—say 20 years. Bearing this in mind the front and rear faces of the dam are to be built of precast blocks of 4 to 1 Portland cement with an additional backing of the same mix. These are keyed together, 5 ft. square, 8 to 12 in. thick and weigh 2 tons. Furthermore, the upstream face is coated with bituminous solution to reduce the possibility of adverse action by peaty waters.

On the basis of the laboratory tests which were made the Board's engineers regard this new material as better than ordinary Portland, though it takes longer to reach its ultimate strength. Among the tests quoted by Mr. Roberts were the construction and strength determination of 3 to 1 mortar briquettes and the suspension of sample briquettes from a raft in Loch Cluanie, these being periodically examined to ascertain the action of peaty water. The specification requires a minimum strength at 28 days of 2,812 lb. per sq. in., and the average worked out at 3,000 lb. per sq. in. Similarly the density specification was 145 lb. per cu. ft., but the actual figure reached was 150.

The great advantage claimed for this process, apart from the saving in cement, is the low heat of hydration, in consequence of which it is hoped to avoid excessive temperature gradient with resultant cracking, and what he called "skyscraper building." He meant that instead of the usual build up of widely spaced blocks it will be possible to lay blocks of concrete 45 feet long side by side and tier by tier.

The slag at the Colville works is quenched with water and passed through a granulating plant producing a substance up to one millimetre size, rather like coarse sugar. It is brought from the works, a distance of about 160 miles, in large lorries and trailers owned by the Mitchell Construction Co. Ltd., two of which can bring up 40 tons a day. It is estimated that 19,000 tons will be required and, being inert, it can be stored in the open.

Arrived at Cluanie, the slag is tipped into hoppers which are linked with the slurry plant by a troughed belt, 100 ft. long and 24 in. wide. This discharges to twin hoppers with distributor rings at the base and so to twin feed belts, fitted with "Adequate Weigh" weighing machines, which deliver to smaller hoppers. From these, combined with a water spray, it is blown

into one of two Edgar Allen ball mills of 5 tons per hour capacity, designed to reduce the material to a fineness of 3,000 sq. cm. per gramme. These ball mills, erected by the Mitchell Construction Co. Ltd., are driven at 152 r.p.m. through David Brown speed reducers by English Electric induction motors of 275 h.p. and 730 r.p.m.

From the ball mills the material is passed through extractors and tested for fineness and consistency. It then passes by narrow launders to one of the two slurry tanks of 60 tons capacity. To prevent the slurry from setting, these are provided with four revolving arms on each of which are two jets admitting compressed air to agitate the slurry. The slurry is withdrawn by Wilfley pumps and sent by pipes to the cement house. Here are two further mixing tanks, into which a 2 per cent. CaCl accelerator solution is added; finally, pipes take the mixture up to the batching plant.

In the Portland cement store, the bags are piled handy for handling by a Coventry Climax truck which can lift 25 bags on a pallet to a feed conveyor which transfers it to the boot of an elevator after passing over knives to cut the bags.

The cement elevator lies between twin cement silos each of 200 tons capacity and is so arranged that the cement can be passed from elevator to silo or from silo to batching plant. At the top of the batching plant the main aggregate belt enters, bringing aggregate from a granite quarry near the plant. It is of 200 tons per hour capacity and a stockpile is maintained; sand is also delivered as required by this belt. There is a connection allowing concrete to be transferred to the moulding shop where the precast blocks are made. Inside the shop they are handled by an overhead travelling crane, and outside by a movable crane which deposits them handy to the cableway.

The batching plant contains bins for various sizes of aggregate and for cement, sand, and slurry, for each of which ingredients there is automatic weighing, and the final mixture is controlled from one large panel in communication with the "walkie talkie" man on the site. From the batching plant the mixture descends to three concrete mixers, one of one cu. yard, the other two of two cu. yards capacity. These discharge to hoppers over a short, slow-running distributor belt and so by a main feed belt to a movable hopper running on rails at right angles to the dam excavation, and below the twin cableways erected by John M. Henderson & Co. Ltd. These cableways, mounted on 180 ft. towers, stretch 2,200 ft. across the valley and each has a Winget cylindrical skip of 4 cu. yards or 10 tons capacity with air-operated doors. The last mentioned hopper is made traversable to follow the lateral movements of the cableways. The dumping of the skips is controlled by the man in the cut with walkie-talkie apparatus and the control towers are fitted with the appropriate aerials to receive his messages. Separate wave bands are provided for each cableway.

Far East Water-Resources Conference

Under the auspices of the Economic Commission for Asia and the Far East, a regional technical conference on water resources development will be held from 17 to 22 May, 1954, in Tokyo, Japan. The purpose of the conference is to provide an opportunity, particularly to the experts of Asia and the Far East, to participate in an interregional exchange of views and experiences gained on those aspects of water-resources development which are of paramount importance to this region and are generally not dealt with by other international technical organisations.

The following aspects of the subject will be discussed at this conference.

(a). Criterion for justification of projects, or for the selection of a project from among alternative proposals; cost and benefit analysis; and methods of reimbursement.

(b). The necessity of sufficient basic hydrological data for appraising available water resources and planning water-resources development projects; minimum length of records and minimum number of stations required in planning and methods for the indirect computation of run-off from rainfall and other records in lieu of records of direct discharge measurement.

(c). Experience gained in the selection of types of structures in water resources development with special reference to the availability of labour, material, and local condition in countries of ECAFE region.

(d). Planning of sediment control works in a river basin; technical features and economic justifications (check dams, torrent-control works, desilting works, and other sediment control structures).

(e). Salient features of important water-resources development projects (planned or constructed) in countries of the region with special reference to multiple-purpose projects.

(f). Organisation for the effective execution of river-basin development; relative merits and suitability of various kinds of organisation such as: Autonomous and semi-autonomous valley authorities; joint management by related states or provinces; execution of work separately by various departments or provinces under a joint co-ordination board, corporation or company under state ownership or joint ownership of the state and private sector.

(g). Standards of methods, records and terminology of hydrological measurements as proposed by the Bureau of Flood Control.

(h). Other items that may be suggested by governments.

Papers on the above aspects and communications on any other allied subject should be sent in not later than the end of December 1953. Intending authors, however, are requested to inform the Chief of the Bureau of Flood Control, ECAFE, Bangkok (Thailand) at an early date the probable title of their paper. Each paper should be preceded by an abstract not exceeding 500 words (about one page). Maps and diagrams should be drawn in black ink on tracing paper or cloth, conforming to the size 11 in. × 8½ in. or multiples thereof.

The conference will be followed by a technical excursion of various river-basin development projects in Japan, including works on flood control, irrigation and drainage, water power, hydraulic research institutes, etc., from 24 to 29 May, 1954.

The Government of Japan is making arrangements for an exhibition to be held during the entire period of the conference.

Damodar Valley Project

The Damodar Project, the first multi-purpose project of its kind in India, envisages the construction of seven dams, a low diversion dam, a barrage and a thermal power station. The first stage, involving the construction of four dams, one barrage and the power station, was commenced in 1949 and is scheduled for completion by 1955-56. When completed, this will cost about £70 million, produce 300 MW of power, irrigate 750,000 acres, control floods and aid navigation. One of the dams, Tilaiya, and the thermal power station, Bokaro, have been completed and were commissioned in February, 1953.

PART ONE

THE Damodar Valley Basin is roughly 8,500 sq. miles in area and has a population of about five million people. It is probably the richest valley in the country, abounding in a variety of industrial minerals, such as coal and iron ore which have made it the Ruhr of India. But the river itself, like most Indian rivers in the Gangetic plain, is capricious, unpredictable and has been the source of recurrent disasters. The Damodar river rises in Western Bihar in the hills of Chhota Nagpur, flows in a generally south-western direction for a distance of approximately 18 miles through Bihar, and continues on the same general course through Bengal, entering the deltaic plains below Raniganj. Some distance below this point, in the vicinity of Burdwan, the river abruptly changes its course to a southerly direction and debouches into the Hooghly some thirty miles below Calcutta. It has eight tributary streams, the principal being the Barakar, which enters the Damodar from the north where it emerges from the hills. The Damodar is 336 miles long and rising at an elevation of 2,000 ft. above mean sea level, it has a gradient of approximately 10 ft. per mile for the first 150 miles, 3 ft. per mile for the next hundred and a foot per mile in the last stretch of 90 miles. The catchment area of the river (Fig. 1) at its mouth is 8,500 sq. miles of which 6,960 sq. miles is the catchment area of the Upper Damodar river above the confluence with the Barakar. The profile of the river is shown in Fig. 2.

Hydrology

The annual rainfall in the valley for the 30-year period 1912-42 has averaged 46·5 in., varying from a maximum of 64·3 in. in 1917 to a minimum of 30·6 in. in 1915. The Upper Damodar basin generally receives a comparatively high rainfall. Between 80 to 95 per cent. of the average yearly rainfall occurs during the monsoon months of June to October. Monsoon storms, which form in the Bay of Bengal and generally travel in a north-westerly direction to reach the valley, are most frequent and of greater intensity during the first half of the season. For example, in 1930, out of the total rainfall of 52 in., 10·5 in. were due to a single storm before August 15, and 7 in. between August 15 and October 15. These concen-

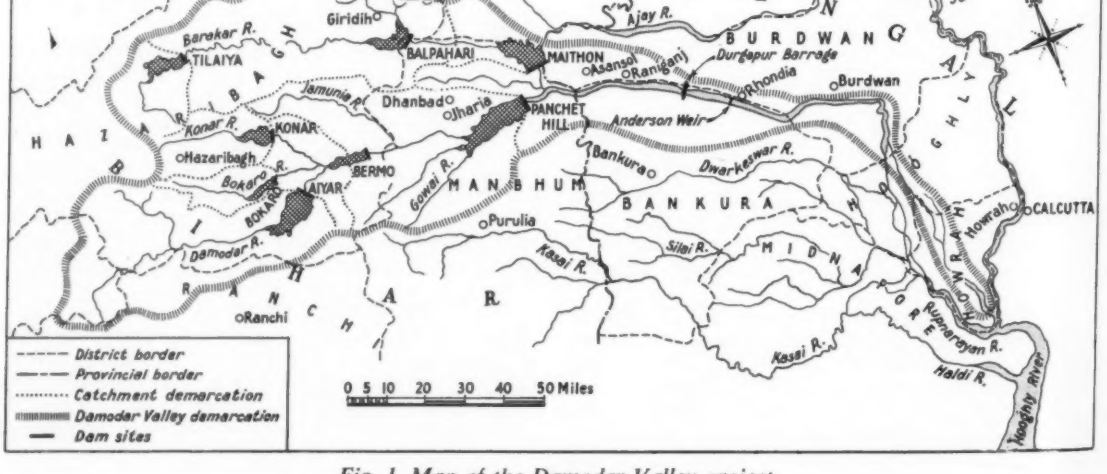


Fig. 1. Map of the Damodar Valley project

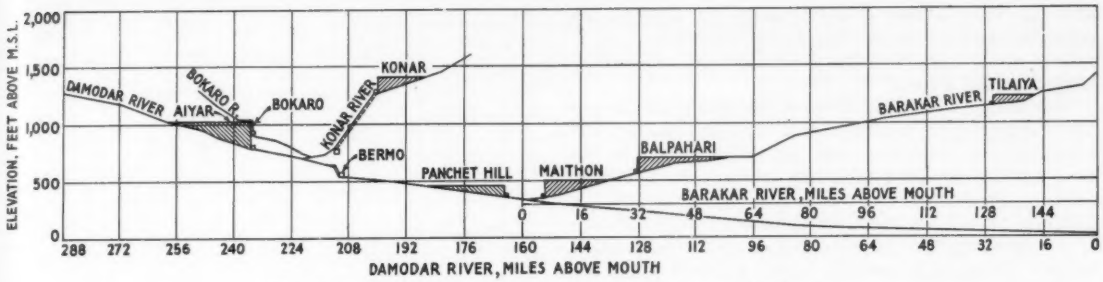


Fig. 2. Profile diagram of Damodar river and tributaries

trated storm precipitations are responsible for very high run-off coefficients and consequently for the disastrous floods that are a regular annual feature of the valley. For a storm which averaged 11·8 in. on the catchment area above Raniganj, the run-off coefficient worked out at 70 per cent. For another storm with an average precipitation of 9·8 in. the run-off coefficient was computed at 84 per cent. These heavy downpours of the monsoon season have led to general erosion of land in the upper basin which is consequently denuded of forests and vegetal cover.

The extent of fluctuation in discharge can be assessed from the fact that while the mean weekly stream flow (for a catchment area of 7,690 sq. miles) averaged about 11,000 cusecs during the twelve-year period 1923-34, the maximum amounted to 128,300 cusecs and the minimum was nil. During the monsoon period, that is from June to October, the average discharge worked out at 25,300 cusecs which, during the dry season, that is from November to May, dropped to an average of 1,060 cusecs. In 1936, a year of comparatively high rainfall, 56·30 in., average discharge during the monsoon was 27,400 cusecs corresponding to a run-off of 20·3 in., and during the dry season it was 2,970 cusecs, corresponding to a run-off of 3·06 in. In 1935, a year of low rainfall of 34·4 in., average discharge figures for wet and dry seasons were 13,600 and 321 cusecs respectively, corresponding to a run-off of 10·1 and 0·33 in. Fig. 3 shows mean weekly discharge over the years 1934-42. The total average yearly run-off of the river at Rhondia has been gauged at 8·10 million acre feet of which 7·63 million, that is about 94 per cent., occurs during the monsoon (Fig. 4).

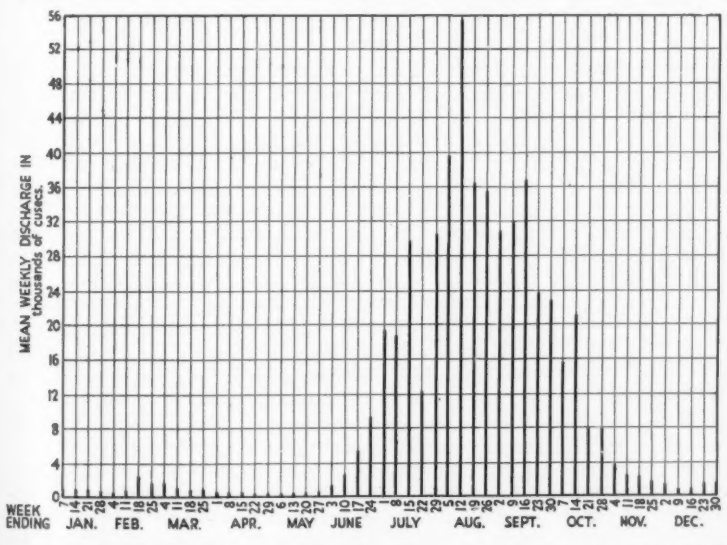


Fig. 3. Natural weekly flow at Rhondia, averaged over the years 1934-1942

Flood Control and Navigation

The months of July and August register on an average about 40 floods in excess of 100,000 cusecs, and a peak flood of 650,000 cusecs, about 25 times the average monsoon flow, has been recorded twice during recent times, viz., in August 1913 and August 1935. Damodar floods are notorious for the disastrous damage to life and property they leave in their wake, and it was these floods and the public clamour for protection against them that led the authorities to devote more attention to the valley as a whole and to initiate extensive exploratory surveys on which to base the flood-control and development measures. The Damodar valley project is thus essentially a flood-control project, the dams and the reservoirs constructed therefor being utilised for power and irrigation. The amount of storage capacity required for flood-control purposes is computed at about 2·9 million acre feet of controlled storage and 500,000 acre feet of uncontrolled storage to which should be added about 950,000 acre feet of dead storage.

"A navigation channel," said the Preliminary Memorandum on the Unified Development of the Damodar Valley, "would not be practicable as a separate development, but the regulated flow from the system of reservoirs makes such a development possible. Without this regulated flow, a series of low-lift dams and locks would have to be provided in the river, and the cost of such navigation development would be prohibitive." A navigation channel with a sufficient depth for river craft with a draught of about 5 ft. would relieve the railways of traffic, at present estimated at 200,000 tons per month, mainly coal, and also encourage two-way traffic from the main city of Calcutta to the agricultural hinterland and vice-versa. The channel, if sufficiently wide, would also help in increasing the present flood-carrying capacity of the river in the lower reaches, which, at present, can carry a maximum

flow of only about 50,000 cusecs as against the required capacity of at least 250,000 cusecs.

Irrigation and Power

The valley is rich in mineral resources and is one of the most highly industrialised regions in India. The abundance of coal and rich iron-ore deposits in the area has led to the foundation of an iron and steel industry producing more than 90 per cent. of the national output. In addition, there are ample deposits of asbestos, apatite, barytes, bauxite, chromite, clays, copper, kyanite, limestone, mica, mineral pigments, quartzite, sandstone, steatite, molybdenite, vanadium and slate. Many of these are already being exploited but a serious lack of power has hampered the progress of development. Among the various new power schemes now under way all over India (WATER POWER, October 1952), Damodar valley basin is probably the only region where the demand for power far exceeds the existing supply. A detailed load survey of the valley and the adjoining areas carried out in 1946 by the Central Technical Power Board revealed the existence of a large and ready market for power. According to the survey there are 13 power stations above 5 MW capacity totalling 260 MW, about 80 per cent. of the total capacity. The prospective additional demand by 1953 was estimated to reach 282 MW, of which 153 MW were to be taken up by heavy and special industries, 33 MW for town and rural electrification, 88 MW for coalfields, and the rest for railway electrification.

The total amount of hydro power which can ultimately be generated from the whole of the project has been estimated at 232 MW, of which about 100 MW would be firm power, the rest varying in duration on an average from 20 per cent. to 80 per cent. of the time. This cannot obviously be expected to meet the anticipated demand; hence the necessity of a thermal station to act as a base-load during the dry season and as a peak-load station during the monsoon. In combination with this power station (initial capacity 150 MW) it would be possible to provide firm power of 300 MW at 60 per cent. load factor.

Irrigation occupies an important place in the economy of the valley, particularly in the lower deltaic reaches where the soil is fertile and rich. But owing to lack of storage, watering of the rice crop in October cannot at present be guaranteed even in those areas that are served by irrigation canals. Thus only about 200,000 acres can at present be partially irrigated instead of the possible irrigable acreage of over one million. It is computed that the discharge capacity of the power installations at the lower reservoirs can conveniently be made sufficient to release 8,000 cusecs, the total maximum estimated demand. This represents a useful reservoir storage capacity of 1·5 million acre feet including allowance for evaporation.

The Unified Plan

After the disastrous floods of 1943, reported to have cost the railways and the Government at least £2-3 million, an inquiry committee was set up by the Government of Bengal whose suggestion that the problem be tackled on the lines of the Tennessee Valley Authority was taken up by a tripartite conference of the governments of India, Bengal and Bihar in 1945. On the recommendation of this conference, the Central

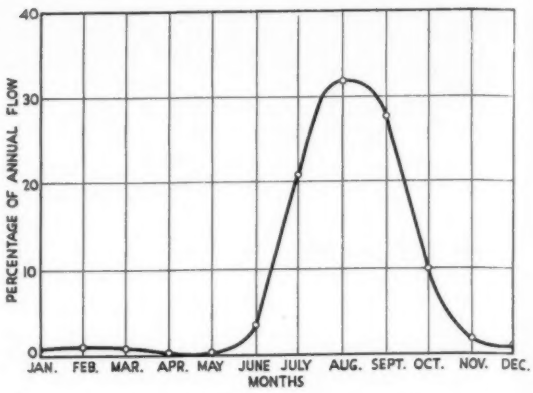


Fig. 4. Average monthly discharge expressed as percentage of mean annual flow (1934-1942)

Technical Power Board prepared the first report in August 1945, which was later that year adopted by the three governments. The report, The Preliminary Memorandum on the Unified Development of the Damodar River, was drawn up by Mr. W. L. Voorduin, the hydro-electric member of the Board and at one time Projects Officer of the Tennessee Valley Authority. Thus was born the Damodar Valley Corporation whose functions, among others, include (1) the promotion and operation of schemes for irrigation, water supply and drainage, for the generation, transmission and distribution of electrical energy, both hydro-electric and thermal; (2) the promotion and operation of schemes for flood control and navigation; (3) the promotion of afforestation and control of soil erosion in the valley, and (4) the promotion of public health and of agricultural and industrial, economic and general wellbeing in the valley in its area of operation.

The scheme, now being implemented, envisages the construction of seven dams, a low diversion dam, a barrage and a thermal power station (Fig. 1). The dams are located at Tilaiya, Konar, Maithon, Panchet Hill, Aiyar, Balpahari and Bokaro. The low diversion dam and a power canal will be at Bermo where the river drops sharply and where a substantial head can be developed for power purposes by utilising a deep gorge and a head of 30 ft. The barrage is located at Durgapur about 15 miles downstream of Raniganj for diversion of water into associated canals and tributaries measuring 1,533 miles. The main left-bank canal, 90 miles long, with a number of locks suitably located, will serve as a navigation canal between Durgapur and Hooghly river thereby linking the Raniganj coalfields with the Port of Calcutta. The reservoirs with their storage capacities and other details are tabulated in Table 1. The ultimate installed hydropower capacity will be 232 MW and just over a million acres will be brought under irrigation. In addition to hydro power there is a thermal power station at Bokaro with an ultimate installed capacity of 200 MW to firm up the seasonal power supply from the hydro stations. The first stage comprises Tilaiya, Konar, Maithon and Panchet Hill dams with a combined ultimate installed capacity of 146 MW, the barrage at Durgapur, and the Bokaro power station. Of these, Tilaiya dam has been completed and was inaugurated by the Prime Minister, Mr. Jawaharlal

TABLE 1: BRIEF DATA ON THE D.V.C. PROJECTS

Dam	Height of Dam	Reservoir storage	Ultimate installed Capacity	Units Generated per Year	Date of Completion
	ft.	million acre ft.	kW	kWh	
1. Tilaiya ...	99	0·32 (Top of Gates) 0·26 (Live Storage)*	4,000 (initial) 6,000 (ultimate)	22,770,000	Completed 1953
2. Konar ...	158	0·26 (T. of G.) 0·21 (L.S.)	40,000	191,000,000	1956-57
3. Maithon† ...	162	1·104 (T. of G.) 0·496 (L.S.)*	60,000	164,000,000	1955-56
4. Panchet Hill‡	133	1·214 (T. of G.) 0·185 (L.S.)‡	40,000	100.000,000	1956
5. Aiyar ...	250	1·33 (T. of G.) 0·731 (L.S.)	45,000	—	2nd Stage
6. Balpahari ...	115	0·407 (T. of G.) 0·211 (L.S.)	20,000	—	2nd Stage
7. Bokaro ...	160	0·160 (T. of G.) 0·08 (L.S.)	3,200	—	2nd Stage
8. Low Diversion Weir at Bokaro	30	Nil.	18,000	—	2nd Stage

NOTES: *Live storage means the storage available for release during the dry period for power and irrigation purposes.
†Maithon is primarily concerned with flood storage and has a controlled flood-storage capacity of 440,000 acre ft.
‡Panchet Hill is also a flood-control project and has a controlled flood storage of 881,000 acre ft.

Nehru, early this year. The Bokaro power station was also commissioned on the same day with the switching on of the first 50 MW set. Another set has since been installed and the third one will go in later this year. All the other projects are scheduled for completion by 1957 at the latest.

The cost of the first stage including the construction of the four dams, the barrage, the thermal station and the whole of the transmission grid has been estimated at £56 million, although revised estimates are under consideration and the final figure will probably be nearer £70 million. The Damodar Valley Corporation (DVC) is an autonomous body with powers to borrow money from internal and foreign sources and is responsible to the Government of India in the Ministry of Irrigation and Power. The Corporation has so far received a loan of 38 million dollars from the International Bank of Reconstruction and Development, of which an agreement for 19·5 million dollars at $4\frac{7}{8}$ per cent. interest for 25 years was signed in January this year.

The Corporation is being advised by a board of consultants including Mr. S. O. Harper and Mr. L. F. Harza from the United States. There are also other consultants for the individual projects. Most of the dam work is being done departmentally, a common feature of all large-scale Indian construction schemes, including Bhakra in the north and most of the dams in the south. Considering the general uncertain post-war economic situation both in the world at large and in India, the progress of works has not been unsatisfactory. An autonomous body is generally always subject to public criticism and the DVC has not been without its due share. Inquiry commissions, however, have revealed nothing more serious than the usual run of irregularities, not uncommon in government institutions of a similar kind. Despite its shortcomings, it would not be untrue to say that the DVC has hitherto kept to its programme timetable—an unheard-of-thing in a country like India. There is no reason why the Corporation should not be able to maintain this pace until the completion of its first-stage work.

(To be continued)

British Standards House

The British Standards Institution is now housed in its new home at 2 Park Street, Mayfair, W.1, and various departments, previously so scattered, have now been gathered under one roof. This move has been accompanied by many advantages, the first being that the 300 members of the staff are able to carry out their work with a much greater efficiency as the contacts between departments and individuals have been greatly facilitated and it has been possible to organise routine functions on a flow basis, with benefit to both efficiency of control and speed of output. From the members' point of view the advantages lie in more and better committee rooms and easier access to the staff personnel.

To celebrate the occasion of the move into its new premises the British Standards Institution held an "at home" to subscribers, committee members, and the press recently and in the course of three evenings managed to entertain over 3,000 guests who were conducted around the eight floors of the building by one or another well-informed member of the staff. The scope of the Institution's activities is impressive, its value immeasurable, and it is all to the good that its activities should thus be freed from what might be termed domestic inconveniences.

Recommendations for Rotating Electrical Machinery. The International Electrotechnical Commission has issued a fifth edition of its Publication No. 34 containing recommendations for rotating electrical machinery excluding traction motors. Transformers, which were included in previous editions, are now excluded and will be treated in a separate publication. The present publication, which is available from 39, route de Malagnou, Geneva, at 5 Sw. fr. net, comprises Part I only of Publication 34. Part II will be devoted to recommendations for the determination of efficiency and will be issued later.

Moulded Plastics for Industry. A handsomely illustrated brochure published by The General Electric Co. Ltd., England, gives an excellent insight into the manufacture and manifold uses of components in thermosetting, thermoplastic and bituminous plasters.

A New Method of Producing Annular Flow

Dipl. Ing. P. U. Weber, lecturer at the Swiss Federal Institute of Technology, Zurich, describes apparatus now in course of development in which the flow can be varied without altering its velocity of swirl and without requiring a multiplicity of moving parts. Possible repercussions on the design of turbines, pumps and other hydraulic apparatus are considered.

IN certain types of hydraulic apparatus, such as reaction turbines, centrifugal pumps, hydraulic transmissions, spray-atomisers and separators, it is necessary to impart rotation to the incoming fluid in a duct or pipe in order to maintain a rotationally symmetric swirling flow. For fluid machines this conversion of an approaching parallel stream into a rotating flow must be achieved with the lowest possible loss, but in certain other flow devices, for instance atomisers, the associated losses may have no or only minor importance. The means for producing the swirl in fluid machines are often used to regulate the quantity of flow.

The method best known today for producing swirling annular flow is by the Fink movable guide-vane apparatus, as employed in turbines, in which the guide-vanes are pivoted about the blade trunnions, and change not only the cross section of the flow but also the swirl angle. Other well-known guiding methods depend on the principle of the jet nozzle, whereby, upstream of the axially movable needle controlling the flow, inclined guide vanes are fixed inside the nozzle. With this method also, the variation of flow area is accompanied by a change in swirl angle. The chief advantage of the Fink type guide apparatus lies in the low losses associated therewith, which, for full opening, amount only to about 1—2 per cent. and, for one-quarter opening to about 3—6 per cent. A great disadvantage of this mechanism is the large number of moving parts, often twenty or more blades being necessary. In contrast to this, the nozzle-type apparatus requires only one or two moving parts, although it invariably gives considerably lower efficiencies than the Fink system, particularly at part opening. This also applies to all other similar contrivances known to us. The above-mentioned guide mechanisms, when serving to produce swirling flow in turbines or pumps with fixed runner blades, invariably suffer from the further disadvantage that the swirl angle only corresponds to the theoretically correct runner inlet angle for one particular opening. All flow areas differing from this optimum opening cause flow-angle variations which lead to increased losses, the so-called "shock" losses. Thus, for example, the efficiency curve of a Francis turbine (runner with fixed blades) is far less flat than that of a Kaplan turbine with blades adjustable and therefore adaptable to angular changes (Fig. 1).

Since 1948, tests were carried out by the Société Financière d'Expansion Commerciale et Industrielle S.A., "Sfindex," Sarnen, Switzerland, on new type guiding equipment (British Patent Numbers 655,370 & 673,062) in order to establish how far it is possible by this means to avoid the disadvantages of many moving parts, swirl angle varying with opening, and

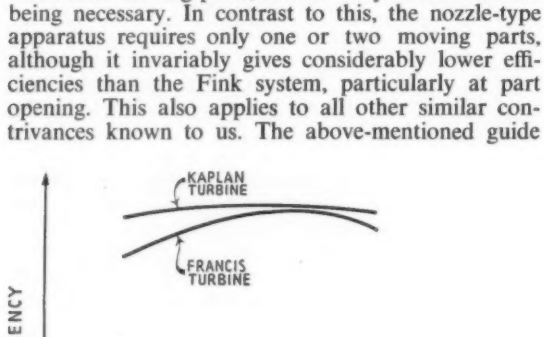


Fig. 1. Typical efficiency curves for Kaplan and Francis turbines

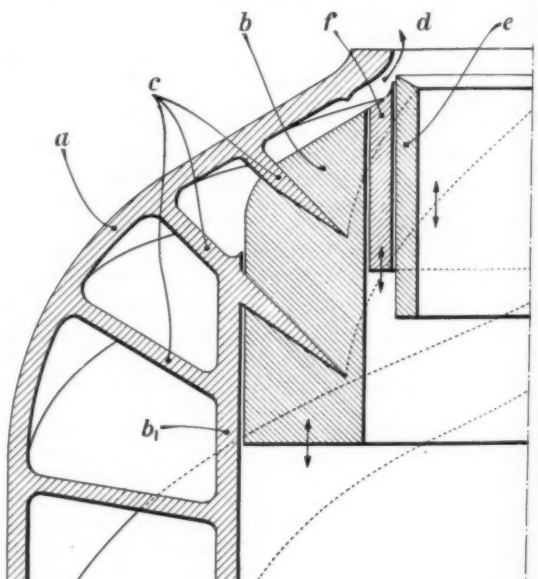


Fig. 2. Section showing principle of annular-flow nozzle

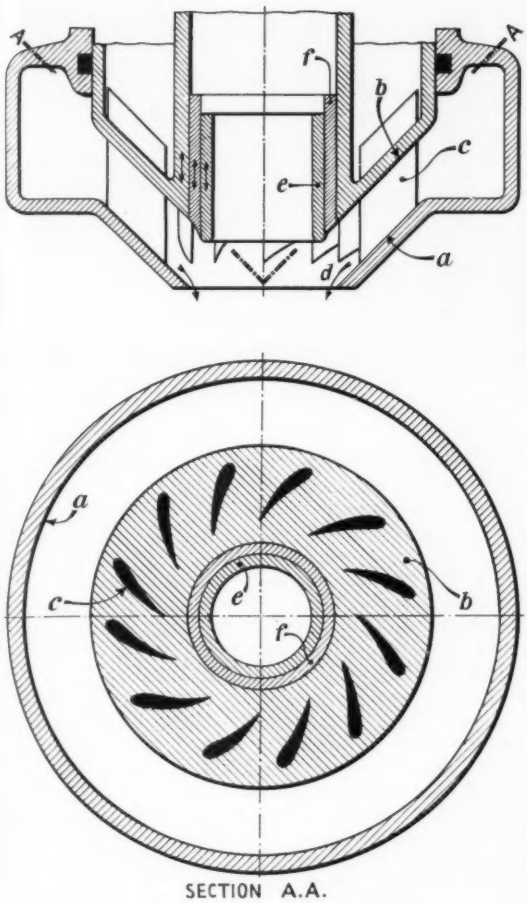


Fig. 3. Annular guide apparatus

poor efficiency of existing devices. In this guide apparatus, surfaces of revolution (See Fig. 2, *a*, *b*, b_1) form the inner and outer boundaries to the flow of fluid. Helical surfaces *c* give the flow the required rotation. For regulating the flow the inner surface of revolution (*b* or for another arrangement, *b* and b_1) can be screwed against the outer surface *a* and thus moved axially. The screw pitch and the profile of the helices need only be constant in the vicinity of the actual mating surfaces. The envelope of the stream annulus issuing from the jet nozzle forms the surface of a hyperboloid *d*. The rotation angle and therefore the asymptotic angle to the hyperboloid remains constant provided that the flow surfaces discharge parallel near the nozzle exit. The swirl component can also further be changed at will by varying the axial position of the angle-control tube *e*. If quick regulation is necessary it can be achieved with the help of the quick-shutting sleeve *f*.

Making the screw pitch infinite for the whole range results in the special annular guide apparatus shown in Fig. 3. The issuing jet from this apparatus gives, in the region of the origin of the hyperboloid, a satisfactory annular flow with constant swirl component (See Fig. 4). The maximum efficiency of this annular jet nozzle was measured as 96 per cent. For part openings, however, it gave unsatisfactory results, as the ratio of the wetted guiding and bounding perimeter to the flow area, which is significant in determining the losses, increased much too rapidly with decreasing opening. By reducing the controlling area of the exit relative to the entry section, the efficiency at part opening can be considerably improved. (Maximum efficiency 97·5 per cent., efficiency at one-quarter opening 93 per cent., nozzle diameter 50 mm.)

After obtaining this result at the end of 1949 it was decided, as a first application of the annular-flow guide apparatus, to construct and investigate a full-admission impulse turbine (See Fig. 5). A series of six different runners had to be designed, manufactured and tested before one of them produced good results appropriate to the small size of model. With the best of the models proposed to date, having a diameter of only 65 mm., a maximum turbine hydraulic efficiency of 78—79 per cent. was measured. This turbine awaits an official test. With the usual step-up formulae used in turbine design and from experimental data a full-scale prototype efficiency of from 85—90 per cent. has been calculated. One realises that the usual formulae should not be applied unreservedly to this turbine, but they form a basis of comparison for assessing the results from a relatively small model. A new theoretically derived formula yields an efficiency of 86—87 per cent. for a turbine of normal large size.

As was mentioned in the letters of patent and made clear in the preliminary studies, the new annular-flow guide mechanism is also likely to lead to innovations, and in certain cases improvements, in the field

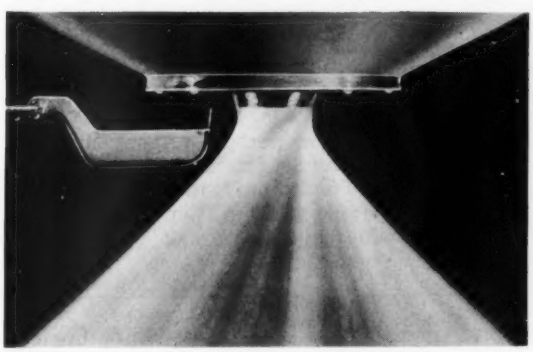


Fig. 4. Hyperboloid-shaped jet formed by the apparatus sectioned in Fig. 3

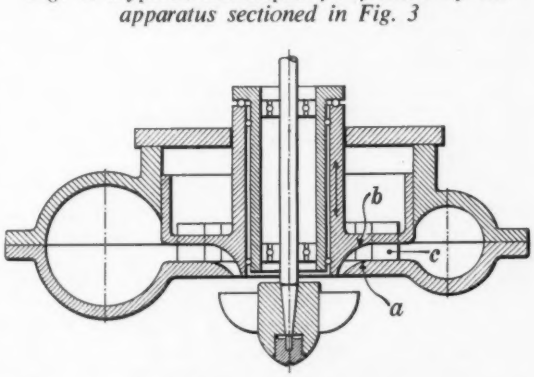


Fig. 5. Full-admission impulse-type experimental turbine utilising annular-flow apparatus

of pump construction. For example it is apparent that the only practical way nowadays of regulating the delivery of a centrifugal pump without incurring energy losses is by varying the rotational speed. For this, either costly gears or variable-speed driving motors are necessary, resulting in correspondingly expensive machines. In most cases the favourable efficiency obtained by speed regulation is foregone and the flow is varied by throttling in the pump (volute sleeve-valve) or after the pump (cylindrical valve or gate valve) according to needs. By means of the bell-like shape of the pump impeller, with an annular-flow diffuser vane mechanism at outlet, it is theoretically possible to obtain almost as loss-free a control as by speed regulation. In spite of the necessarily more complex construction, increases in cost are certainly less than for speed regulation. Experiment, and later experience with the prototype, will show in which manner the gain in efficiency pays for the extra cost. Studies are also being made regarding the application of the annular-flow regulating principle to the pump impeller itself.

Since a hydraulic transmission consists technically of the combination of turbine and pump, it is not a far step to apply the annular-flow principle to this field also. Preliminary studies have revealed that researches in this direction are certainly justified and are capable of leading to improvements.

As already mentioned, applications of the annular-flow principle also extend to those fields where the efficiency of flow is not important. Thus, for example, the applications have been investigated of a simple annular-flow device for spraying purposes. The apparatus was connected to a town water supply. The area covered and the intensity distribution of the spray were measured by means of rows of exposed collecting pots, for pressures ranging from 1 to 3 atm. and flows from 10 to 70 cu. m. per hour. In spite of the apparatus working without automatic throw changing the results obtained were satisfactory. (See the " veil " of water in front of the tree trunks on the right-hand side of Fig. 6.) Similar applications to further analogous fields are at present being examined.

Fig. 6. Annular-flow device used as a sprinkler

Summing up, it can be said that the previously mentioned disadvantages of a multiplicity of moving parts and the dependence of the swirl angle upon opening do not occur with the new annular-flow apparatus. The efficiency, for those applications where this is of particular importance, should be almost or just as good as for similar existing control devices. It is to be expected that the technical difficulties of construction, mastery of which undoubtedly has an important influence as for instance with Fink guide apparatus, are comparatively more easily overcome. As regards the bearing of the application of this principle to turbine construction, it should be pointed out that this full-admission impulse turbine can be used in the overlapping region, which is not satisfactorily covered at the moment, between twin-jet impulse turbines and the low-specific-speed Francis turbines for high heads. The previous submissions should certainly not yet be regarded as the best possible results from model tests, but rather as very satisfactory if the usual scale-up rules, particularly with regard to the effect of head, are allowed to be applied to the proposed device. Tests and theoretical considerations lead us to expect that the consequences of this will be far reaching.

Contract for Wadi Tharthar Sluice Gates

Ransomes and Rapier Limited, of Ipswich, have been awarded a contract for the construction of sluice gates and operating gear for the Government of Irak. This £570,000 contract was secured in the face of stiff competition from German, French and Austrian firms. Ransomes and Rapier were the only British firm to tender for this contract, which, we understand, was awarded not on price but on design and quality of materials.

This contract is for the Wadi Tharthar project, about 100 miles north of Bagdad, and entails the construction of 17 barrage gates, each 40 ft. span by 16 ft. deep and 28 regulator gates, each 40 ft. span by 21 ft. deep, complete with operating gear. Nearly 4,000 tons of material will be involved in their construction. All the work will be carried out at Waterside Works, Ipswich, and will be shipped to Basra for Bagdad. The Wadi Tharthar scheme will enable the flood waters of the river Tigris to be stored in a depression in the desert. During the low river season the stored water will be returned to the Tigris, increasing the supply of water for irrigation.

Many projects for the Government of Irak have been undertaken by Ransomes and Rapier, notably the Habbaniyah barrage on the Euphrates, the Ramadi barrage and regulating gear, also on the Euphrates, and the Kut barrage on the Tigris.

Gaur Power Station. No. 17 of *Switchgear News*, received from Cooke & Ferguson Limited, of Manchester, gives a brief description of the North of Scotland Hydro-Electric Board's latest station and an account of the switchgear and other electrical equipment they supplied for this scheme.

G.E.C. List of Products. To assist the consumer, The General Electric Co. Ltd. have issued a full list of the range of mechanical and electrical equipment manufactured by themselves and their associated manufacturing companies. For overseas customers the value of this list is further enhanced by a supplement which gives the names of the many overseas agencies who handle G.E.C. products.

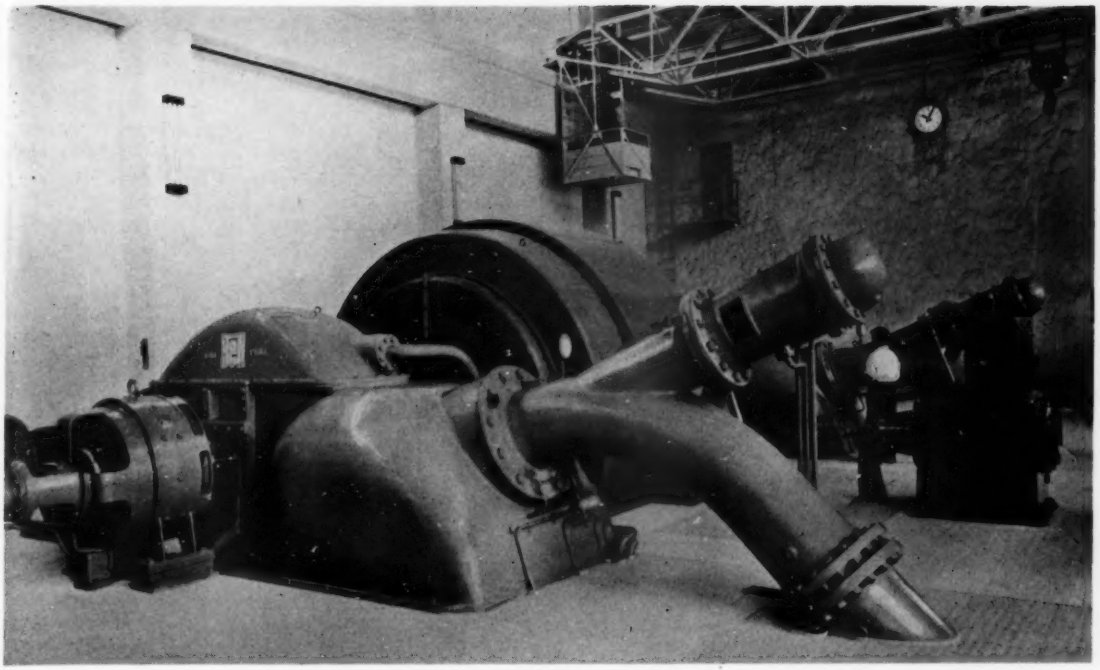


Fig. 10. One of the Bell / Brown-Boveri 30,000 kVA generating sets

The Juan Carosio-Moyopampa Power Station

A description of a Peruvian development in which a 42 MW station on the Rio Santa Eulalia provides much-needed power to Lima and district.

PART TWO

Mechanical Equipment.

Control valves. A Bell spherical valve 650 mm. in diameter is fitted in front of the inlet to each turbine. The essential parts of this valve are a body fabricated in halves with a brass seating which can be easily dismantled, a plug with a bolted-on seating, a servomotor controlling both lift and rotation of the plug, and an automatically controlled bypass. In addition, flush and drain pipes are fitted on to the bottom half of the valve body. Control is effected by means of a simple and reliable pilot valve. The working of the control valve can be followed by reference to the left-hand end of Fig. 11. The most conspicuous characteristics claimed for the Bell spherical valve are the absence of movable components and seals inside the body, robust seating with large contact faces, which at full water pressure ensure a drop-tight fitting, and the simple and reliable operating gear.

Turbines. Various considerations, particularly reasons of economy, determined the selection of two two-jet Pelton turbines for each unit, the runners being attached by flanges to either end of the generator shaft so that each unit has but two bearings. These turbines are designed for a head of 456 m., a water flow of 2 × 2·66 cu. m. per sec., and a maximum output of 31,300 h.p. at 514 r.p.m. As seen in Fig. 13, the control valve is connected to a Y-pipe by means of a flange which ensures easy dismantling. The nozzles are fitted to the other end of the Y-pipe so as to form an angle of 45°, and their connection to the turbine casing is designed in such a way as to give easy access to the runner for inspection or repairs. The runner itself is a 45 kg. per sq. mm. solid steel casting, and all surfaces subject to erosion are reinforced by a weld-deposited layer; the lower part of the casing has a double shell inside which channels are provided for the ventilation of the whole casing as well as for drainage. A cast-steel shield protects the rear section of the casing when the jets are deflected. A platform, accessible through a door from the basement of the power house, is provided for inspection of the nozzles, deflectors and runner.

Governing gear. The deflectors and spears of each turbine set are actuated by a speed regulator operating as shown in the schematic diagram, Fig. 13. The main characteristic of this apparatus is the constructional independence of its most important members, such as the receiver responsive to speed 33, the distribution valve 27, and the cataract regulator 34 with its rigid and flexible return - motion mechanisms. This arrangement enables an electric actuator to be substituted for a centrifugal governor, and owing to the very small power required by the other members of the gear, this actuator can operate without any pilot mechanism. All these components are housed in a cabinet the front panel of which carries all the instruments and gauges necessary to the operation of the whole control gear. The actuator cabinet is located above the main servomotor, which, together with the upper oil tank 23, the lower oil tank 51 and the oil cooler 62, forms a closed construction unit which also comprises the Imo oil pumps 52 and 53, driven by an electric motor and a small impulse turbine respectively.

The electric actuator manufactured by the Brown-Boveri concern in Baden is fundamentally a frequency or speed-measuring device which consists of two metering elements 33a and 33b, and a variometer 33c. The stator windings of both elements are fed from the voltage transformer of the generator or from a separate small three-phase generator mounted on the turbine shaft in such a way that the two rotating fields work in opposition to each other. The circuit of one of the stators is capacitive, owing to the interposition of a three-phase condenser 33d, whereas the circuit of the other is inductive. At normal frequency, the two rotating fields balance each other, and the governor spindle does not rotate; at the slightest variation of frequency, one torque overcomes the other and the spindle rotates accordingly one way or the other. Variometer 33c produces inductivity in one of the circuits, and its rotor, when moving from zero position, exerts an increasing counter torque on regulator spindle 33e. As soon as this couple equals the resultant couple of both measuring coils, the spindle stops. Thus for each frequency this spindle assumes a position of equilibrium, which gives the apparatus a static characteristic. The action of the apparatus is fundamentally independent of the voltage; only in cases of complete voltage failure would the governor spindle stop in an indeterminate position, but this is checked by the weight of the control linkage, which is designed to feed the spindle towards the closed position.

In the case of load variations, as for example when load decreases, spindle 33e rotates in the direction shown by the arrow in the diagram and feeds control valve 28 downwards by means of needle 29 which covers a leak-off in the control-valve piston. The annular space on the right side of piston 21 is thus brought into connection with the outlet, whereupon spring 22 rotates spindle 24 so as to move deflector 2 into the path of the jet. At the same time, the associated linkwork, acting through spring member 11, moves pilot valves 9 of the spear servomotors by means of abutment 10, in a direction to move the spear servomotors towards the closed position. The speed of this motion is restricted by diaphragms inserted in the oil circuit and set to maintain the temporary rise of water pressure in the penstocks within admissible limits.

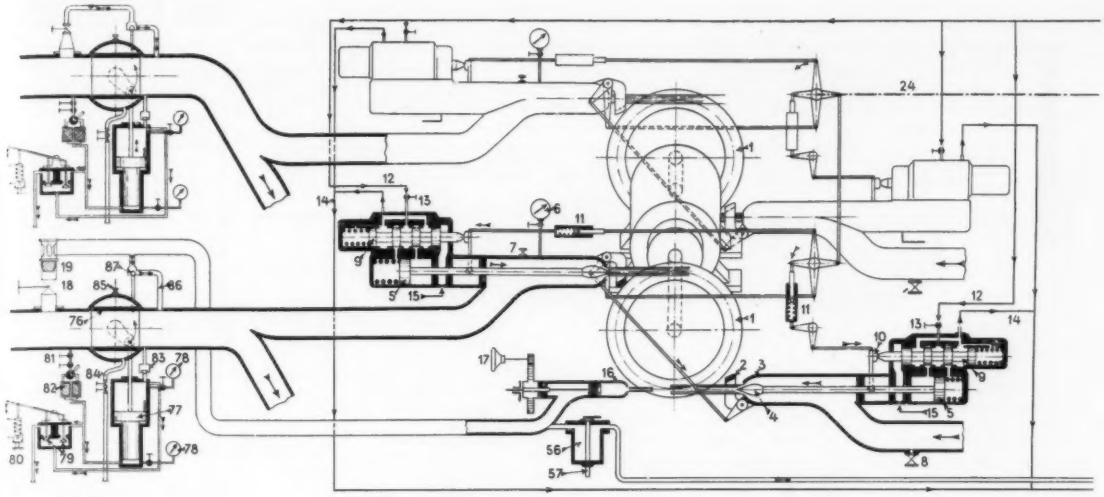
The rigid return motion is controlled by means of piston 34 and links 44a and 44b, which are actuated from spindle 24 through a linkage and an inclined plane, and move the right-hand end of floating link 36 in a direction to restore valve 28 to its central position. If this device alone were employed, the speed fluctuation caused by load rejection would take the form of a series of gradually diminishing oscillations, and to avoid these oscillations a flexible return-motion mechanism is provided, which consists of a cataract piston 35 and temporarily boosts the return motion to a considerable extent. This piston is normally held in its mid position by spring assembly 46 If piston 34 moves, the oil cushion also causes piston 35 to be carried with it and to move the end of lever 36a in the same direction, but this movement compresses spring assembly 46 which gradually restores piston 35 to its original position.

Under the action of these various devices the governing process develops as follows, for instance in the case of a load rejection: First of all, deflectors 2 fully divert the jets in a few seconds, as described, and spears 4 advance and reduce the flow. As the speed decreases, the return motion comes into operation, spindle 24 rotates in the opening direction, deflectors 2 move away from the jets, and the spears permit the admission of such a volume of water that the rotors of the unit revolve at a higher speed corresponding to the load/speed characteristic This characteristic can be adjusted by moving roller 37, that is to say the fulcrum of lever 44a, and the setting can be checked on indicator 38. When the generators are working in parallel, speed and load can be varied by means of the handwheel 42 and the motor 43 respectively.

At a determined position of piston 34, the upward motion of pilot control needle 29 is restricted by linkage 39, so as to prevent a wider opening of the turbine inlet. The degree of load restriction can be altered by means of handwheel 41, and its setting can be checked on indicator 40. In the case of major load rejections, the flexible return motion should operate to a limited extent only in order not to slow down the closing speed; for this purpose, piston 35 has a valve 47 at its centre, which is loaded with an adjustable spring, and opens as soon as oil pressure in the upper cushion exceeds a predetermined value.

Abutments 10 in the linkage of the spear control gears are designed to enable deflectors 2, at any load, to be positioned but a few millimetres away from the water jets so that they can operate very quickly in the case of load rejections. When it is necessary to put a nozzle out of operation, the admission of pressure oil is interrupted by means of valve 13.

When a generating unit is to be started, auxiliary turbine 53 is first put into operation by means of control valve 54, so that oil under pressure is available at once. Oil is then admitted under plunger 31 by means of pushbutton 32, whereupon link 36 rises, the spears recede from their closed position and the turbine starts. As soon as a moderate speed has been attained, the voltage produced in the primary generator of the speed governor is sufficient to maintain spindle 33e in its open position, and the pushbutton can be released. It is also possible to switch on the motor to oil pumps 52 and to stop auxiliary turbine 53 by remote control



Turbine
1. Runner
2. Jet deflector
3. Nozzle
4. Spear
5. Spear-servomotor piston
6. Power water-pressure gauge
7. Air exhaust valve
8. Drain cock
9. Main control valve to 5
10. Abutment
11. Elastic governing linkage to 9
12. Pressure oil pipe to 5
13. Stop valve to 12
14. Oil return pipe
15. Oil drain
16. Braking nozzle
17. Handwheel to 16
18. Slide valve to 16, also acting as bypass valve to 76
19. Filter

Governor
21. Piston of main servomotor
22. Closing spring
23. Upper oil tank
24. Governor spindle
25. Oil-pressure safety valve
26. Oil-level indicator
27. Governor valve casing
28. Control piston
29. Control rod to pilot control gear
30. Oil-pressure gauge
31. Starter
32. Pushbutton to 31
33. Brown-Boveri actuator
33a, 33b. Measuring coils
33c. Variometer
33d. Condenser
33e. Actuator spindle
34. Cataract
35. Cataract piston
36. Governor lever
36a. Floating lever
37. Speed-droop adjustment
38. Speed-droop indicator
39. Load-limiting device
40. Load-limit indicator
41. Handwheel to 39
42. Speeder-gear handwheel
43. Speeder motor
44. Rigid return-motion linkage
45. Emergency stop button
46. Flexible return-motion springs
47. Overpressure relief valve
48. Spear position indicator

Oil pump
51. Lower oil tank
52. Motor-driven service oil pump
53. Emergency oil pump, driven by auxiliary turbine
54. Control valve to auxiliary turbine
55. Handwheel to 54
56. Rotary filter
57. Drain
58. Non-return valve
59. Maximum-contact pressure gauge
60. Oil pressure pipe
61. Diaphragm
62. Oil cooler
63. Cooling-water inlet
64. Cooling-water outlet
65. Oil overflow pipe
66. Oil-pressure regulator
67. Float contact
68. Regulating needle to 53
69. Servomotor to 68

Spherical control valve
76. Spherical plug
77. Differential piston of servomotor
78. Water-pressure gauge
79. Pilot valves
80. Closing magnet
81. Slide valve
82. Double filter
83. Non-return valve
84. Drain
85. Air vent
86. Bypass
87. Valve controlling bypass

Safety apparatus
91. Safety governor
92. Oil draining valve
93. Magnet
94. Closing contact

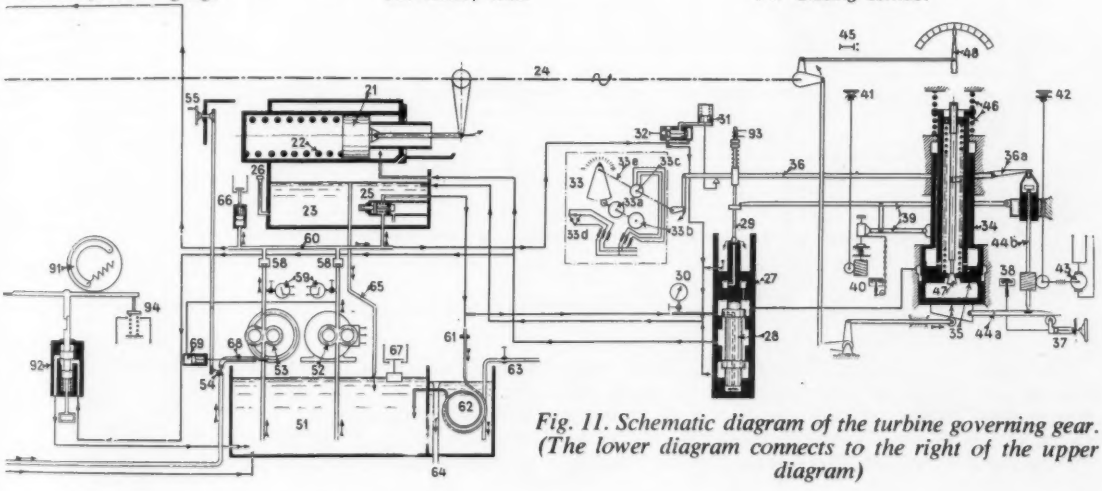
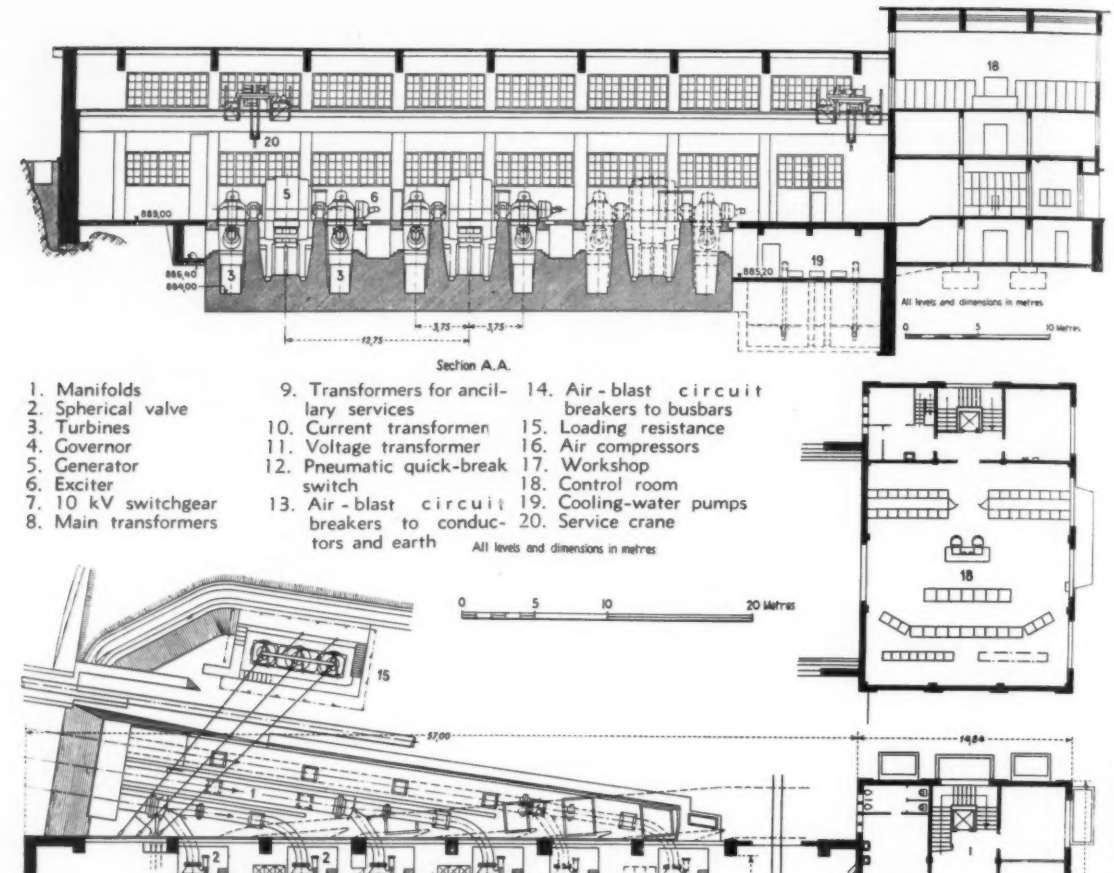


Fig. 11. Schematic diagram of the turbine governing gear. (The lower diagram connects to the right of the upper diagram)



1. Manifolds
2. Spherical valve
3. Turbines
4. Governor
5. Generator
6. Exciter
7. 10 kV switchgear
8. Main transformers
9. Transformers for ancillary services
10. Current transformer
11. Voltage transformer
12. Pneumatic quick-break switch
13. Air-blast circuit breakers to conductors and earth
14. Air-blast circuit breakers to busbars
15. Loading resistance
16. Air compressors
17. Workshop
18. Control room
19. Cooling-water pumps
20. Service crane

Fig. 12. Plan and elevation of Moyopampa power station

The turbine is protected against loss of oil pressure as well as against overspeed. In the case of partial or total failure of pressure in the oil pipe between pump 52 and non-return valve 58, servomotor 69 actuates a spring which opens the auxiliary-turbine nozzle, so that auxiliary pump 53 starts running at once; upon pump 52 being switched on again, oil is fed to servomotor 69 on the closure side, and auxiliary pump 53 stops automatically. If this step proves ineffective, contact pressure gauges 59 close an

emergency circuit whereupon magnet 93 sets control valve 28 in the closing position by means of needle 29 of the pilot control gear. A further safety feature is that all servometer pistons are spring loaded and arrest the water flow as soon as oil pressure fails. In cases of emergency, quick-closing valve 92, operated either by safety governor 91 or by hand, releases the oil under piston 21, causing spring 22 to bring the deflectors rapidly in front of the jets. At the same time, contactor 94 closes the auxiliary circuit of the failure signal, which, in its turn, causes magnet 93 to force the piston of control valve 28 to its closing position. A braking nozzle 16, actuated by hand-wheel 17, is provided for one turbine in each generating unit, which can thus be stopped very rapidly in cases of emergency.

Supply of cooling water. About 200 cu. m. of cooling water are required per hour by the two 30,000 kVA generators and their transformers. The water is drawn from the tailrace, passes through a filtering chamber fitted with fine screens and is subsequently delivered through a ring main by means of two pumps, one of which is a standby, to the coolers, whence it is finally returned to the tailrace. In the case of a prolonged stoppage of both pumps at the same time, a 200 cu. m. tank, connected with the ring main, ensures the supply of cooling water. This tank can also be filled direct from the penstocks through a separate pipe fitted with a pressure-reduction valve.

Electrical Equipment

Generators. The main characteristics of the three-phase alternators supplied by the Brown-Boveri Company in Baden, are as follows:—

Rated capacity (power factor = 0·7)	30,000 kVA
Rated voltage	10,000 V
Frequency	60 c.p.s.
Speed	514 r.p.m.
Flywheel effect	200 ton-metre²
Heaviest items of machinery:—	
Shipping weight (rotor and shaft, exclusive of poles	45 m. tons
Erection weight (rotor complete)	62 m. tons

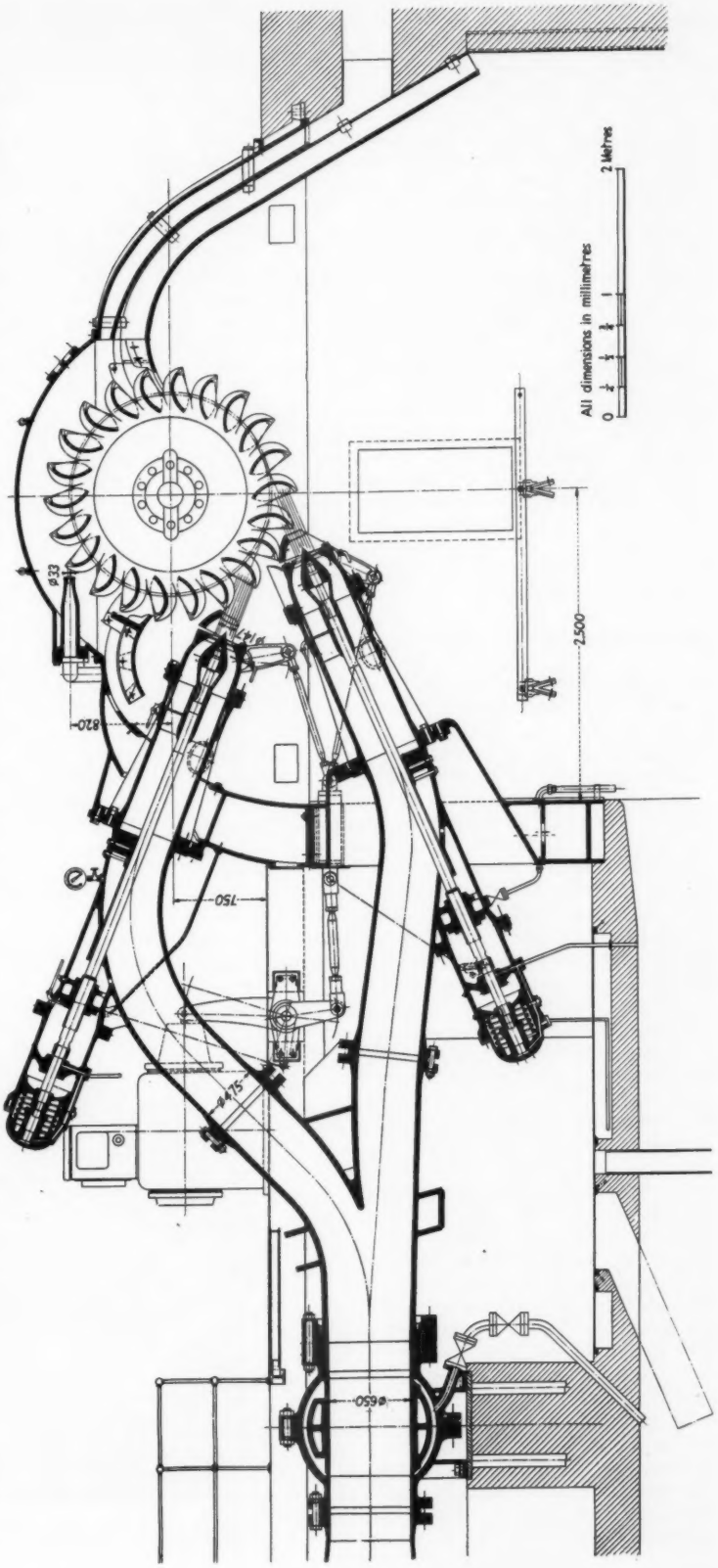


Fig. 13. Sectional elevation of one of the 31,300 h.p. Bell turbines through the plane of one of the runners

The exciter, the pilot exciter and the actuator generator are all mounted in each unit on the overhung end of the shaft extending from the left-hand turbine, as seen from the rear. Ventilation of the generators is on the closed system.

The generators are protected by thermal relays combined with overload trip, overvoltage relay and differential current relay against internal failures and short-circuits. Stator and rotor windings are controlled by balanced-current relays and earth-fault relays, and the temperature of the cooling air and of the bearings is checked by thermostats. All these control devices act on a system of warning relays divided into three groups: danger signals, emergency trips and service trips. The fire-protection system attached to each generator is applied either automatically by means of thermostats, or operated by hand mechanically or electrically, as required. All the necessary instruments and signal relays provided for the service supervision of the generators, together with the voltage regulator and its adjusting resistance, are mounted on a switchboard located in the immediate vicinity of each generating unit. In normal service all switching or control operations are effected from the control room, but the generating units are started from the machine hall upon telephone instructions from the control room.

Transformers and Switchgear

All the energy produced at the power station is conveyed to Lima and the neighbouring districts over a 60 kV four-conductor transmission line 40 km. in length. It was thus possible to simplify the circuit diagram (Fig. 16) accordingly, so as to ensure easy supervision of the whole electrical system.

As previously mentioned, in view of local conditions, the whole of the high-voltage gear is located indoors. As shown in Fig. 12, transformers and switchgear are housed in a two-bay building adjacent to the machine hall, the floors of the two buildings being at the same level. Each generator, working in connection with its group of transformers, feeds the 60 kV double busbars from which the overhead transmission lines lead to Lima and to the Juan Carosio power station.

Transformers. The group of transformers attached to each generator consists of three 10,000 kVA single-phase star-delta units stepping up from 9,500 to 63,000 V at full load and 0·7 power factor, with a short-circuit voltage variation of 9 per cent. Each transformer has a built-in oil cooler with pump, water being the cooling agent. Each oil cooler can be cleaned separately at reduced load without having to interrupt the service of the power station. The transformers are protected against internal failure by Bucholz and differential relays, and are also fitted with a contact telethermometer and water-control instruments. Each group of transformers is housed in its own cubicle.

The selection of single-phase transformers was dictated in this instance by transport difficulties, as each transformer, when oil filled, weighs 13·25 metric tons. Each transformer is mounted on a bogie running on a track by which it can be moved under the crane in the machine hall.

For auxiliary services there are three step-down 320 kVA three-phase transpormers with natural air cooling, two for 64,000/235-135 V, and one for 10,300/235-115 V.

10-kV Switchgear. This gear comprises only the switching apparatus interposed between the generators and the transformer groups, the supply line to the load resistance, and the equipment ensuring the supply of current from outside sources for internal requirements. The connection between generators and transformers consists of open-type copper busbars, and the generators and transformers can be coupled crosswise through an auxiliary busbar by means of air-blast circuit breakers. The 10-kV voltage transformers, as well as a small transformer for the motor driving the oil pump of the governor, are located in the cubicles of the circuit breakers of the transformer groups. All instrument transformers are dry insulated, and the current transformers are of the short-circuit-proof column type.

The adjustable water-load resistance provided for load and regulation tests of the generating units is designed for dealing with outputs up to 30,000 kW; the necessary water is drawn from the penstocks and its pressure is reduced in an energy dissipator provided for other purposes as well.

60-kV Switchgear. This section of the plant is located in a bay parallel to the transformer bay, this indoor setting being selected because of the absence of oil-filled apparatus which rules out the production of soot. This switchgear and associated apparatus comprise all the necessary equipment for three sets of generators and transformers, six overhead transmission lines, excitation, the two transformers for auxiliary supply, as also a double-busbar system, and the 10 kV switchgear for the supply of current from the Chosica plant for internal requirements. The air-

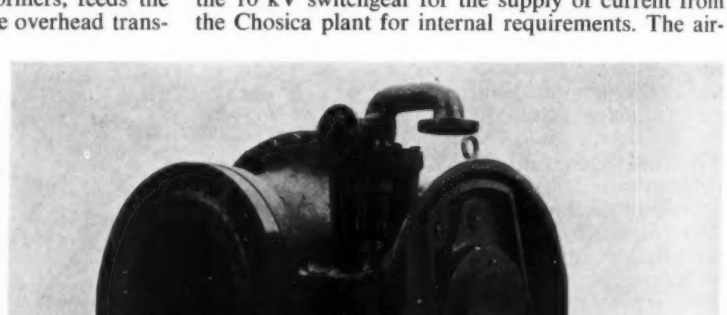


Fig. 14. Spherical valve before installation

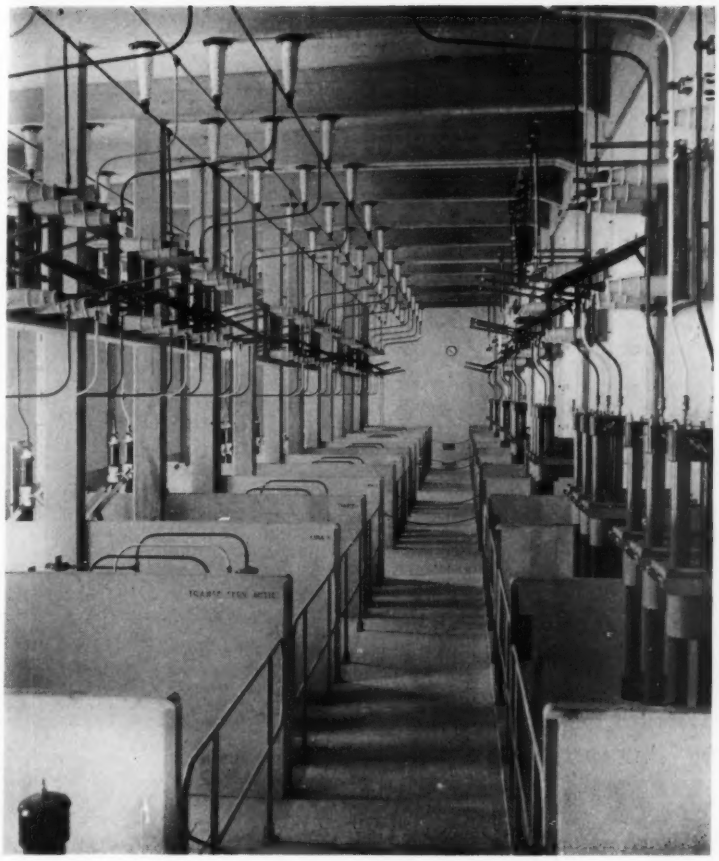


Fig. 15. Bay housing the 60 kV switchgear; this bay is adjacent to the transformer bay and both are on the same floor level as the main machine hall

blast circuit breakers have a three-phase rupturing capacity of 600 MVA; the 60 kV disconnectors are also actuated by compressed air. The voltage transformers have compressed-air insulation, and the current transformers dry insulation.

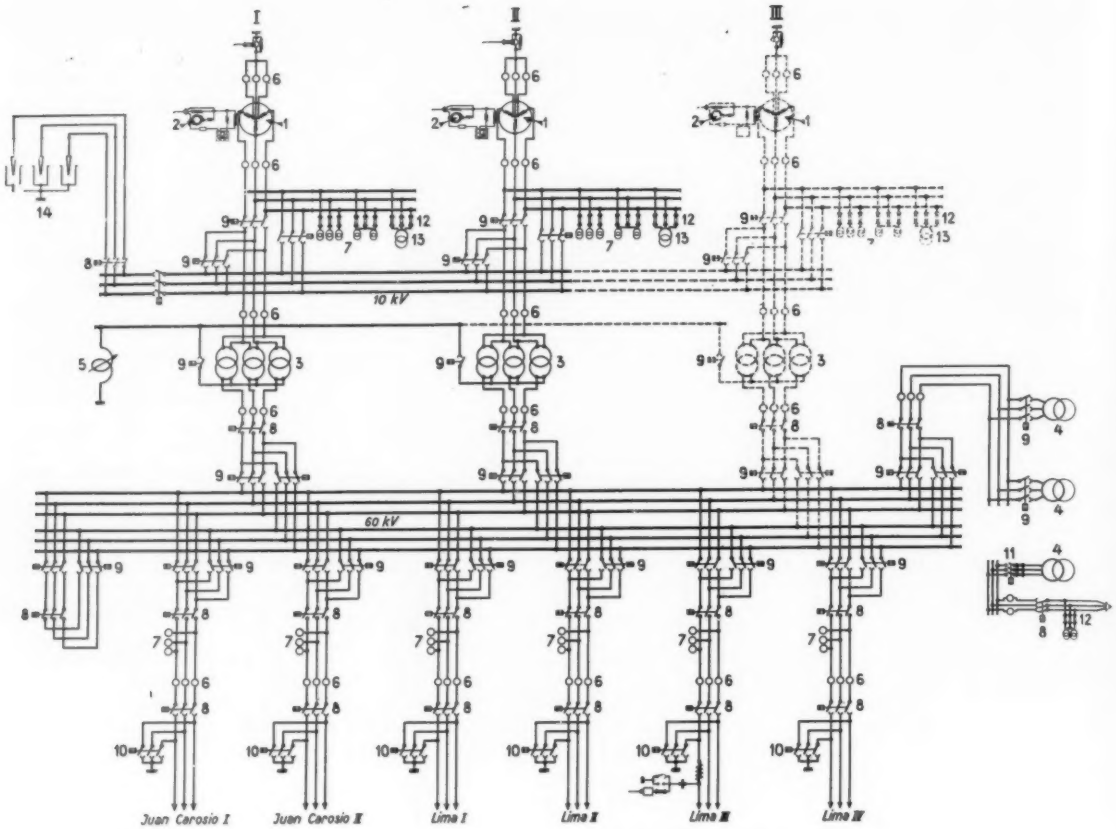
Control Room. Routine supervision of the operations of the power station is effected from a control room located on the second floor of the offices building; a large window gives an unimpeded view of the whole machine hall. An instrument board, standing behind the control desk, carries the connection diagram and all instruments required for the running of the plant. On the opposite side of the room are the various protective devices for the generators, transformers and transmission lines, as well as a remote indicator operated from the surge tank, and the trips to the butterfly valves. The transmission lines are protected by Brown-Boveri relays. The switch panels of the d.c. and a.c. auxiliary services and the meters are not directly visible from the control desk.

Auxiliary Services. Whenever required, the current supply for internal consumption at the power station can be drawn from the Santa Rosa plant in Chosica through a 10 kV line. This 10 kV system is also connected with the electrical apparatus located in the surge tank. The structures supporting the transmission line to the surge tank also carry, at a safe distance from the conductors, a telephone and signal cable which, among other duties, carries the tripping circuit for the butterfly valves.

Direct current is supplied by a battery of accumulators with a capacity of 216 Ah at 130 V and charged by a selenium rectifier. In addition to the control and signal circuits, the battery also feeds the emergency lighting installation, which, in the case of a failure in the a.c. main system, is connected automatically to the accumulators. A pilot clock in the control room synchronises all the connected clocks in the power station, and it is planned to use this pilot clock at a later stage also for the synchronised operation of the recording instruments. Two reciprocating compressors and two compressed-air tanks supply compressed air to the circuit breakers and disconnectors at a pressure of 12 to 14 atm.

Thanks to the high-frequency telephone system between the power station and the Santa Rosa plant, which is the centre of energy distribution in Lima, the management of the station has at its disposal and under its own control a reliable network of telephone connections. This system is connected with both the private manual exchange of the station, and the public network.

The Swiss manufacturers who supplied the equipment of the Moyopampa power station had but a very small personnel of their own to attend to the erection of the machinery; the Bell Company had only one man on the spot, while the Brown-Boveri concern had no more than four electrical fitters. Six Europeans, the majority of them Swiss who had just concluded their apprenticeship, were discovered and enlisted in



1. Generator
2. Exciter
3. Main transformers
4. Auxiliary transformers
5. Earthing coil
6. Current transformers
7. Voltage transformers
8. Pneumatic switches
9. Air-blast circuit breakers to transmission lines
10. Air-blast circuit breakers to earth
11. Air-blast circuit breakers
12. Fuses
13. Transformer to turbine regulation
14. Loading resistance

Fig. 16. Circuit diagram of Moyopampa power station

Lima. Otherwise the auxiliary personnel consisted exclusively of Peruvians, some of them excellent mechanics or electricians. Erection work was under the management and supervision of the Electro Peruana S.A., the Peruvian representatives of both manufacturers, and proceeded at such a pace that the first generating unit began to supply energy to Lima fifteen months after erection had commenced; the second set following six months later — a highly creditable performance under the difficult conditions obtaining at Moyopampa.

NOTE.—This article originally appeared in German in the Swiss journal *Schweizerische Bauzeitung*, Nos. 3 and 4, 1953.

Present Trends in Surge Tank Design

An important paper on the above subject was read by Dr. C. Jaeger on November 6 before the Institution of Mechanical Engineers.

The author summarised the well-known theory of surges in surge tanks, dealing chiefly with the fundamental equations and introducing some preliminary remarks on the stability of surges. He then described the different types of surge tanks, ordinary cylindrical tanks, tanks with variable section and expansion or reservoir chambers, tanks with restricted orifices, and differential surge tanks, with special mention of surge tanks in conjunction with underground power stations.

The loading conditions to be adopted were discussed and the reason why load changes on the electrical grid are the prime cause of surges was explained. The basic assumptions adopted for surge calculations by Italian, Swiss, French, and British engineers were reviewed, and it was shown that, in spite of many apparent disparities on special points, there is widespread agreement on fundamental questions. The interaction of surges, water hammer, and turbine governing was discussed in the light of the most recent tests on large power stations and of the results of modern theories, and the importance of the influence of water hammer on surge tank design was considered together with the special case of surge tanks connected to feeder canals.

We hope to deal with Dr. Jaeger's paper more fully in our next issue.

Fig. 1. General view of Vila Nova power station

Vila Nova

Particulars are given of this important development which forms part of an integrated scheme for supplying Portugal with hydro-electric power.

BRITISH engineers and manufacturers are playing a large part in the new projects designed to promote industrial development in Portugal. In 1944, late on in the War, the Portuguese Government introduced legislation dealing with the re-organisation of industry and the electrification of the country. This made it possible to utilise fully the water power resources available in northern and central Portugal. In order to give effect to this legislation, in the following year three Companies were formed—the Hidro-Electrica do Zezere and the Hidro-Electrica do Cavado to handle the production of electrical energy, and the Companhia Nacional de Electricidade for transmitting the power to the main centres of demand. In view of the importance of the work to be undertaken, the Portuguese Government participated substantially in the finance and administration of these Companies.

Whilst the Portuguese Government were formulating their plans, two British Companies—The English Electric Export & Trading Company Limited and Metropolitan-Vickers Electrical Export Company Limited, acting together, sent engineers to Portugal to confer with the Portuguese engineers who had been appointed to study various hydro-electric projects. These two Companies became known in Portugal as the "British Group" and in 1945 this Group was able to put forward comprehensive proposals for harnessing the available water power. After further discussions the two Portuguese power companies placed contracts with the Group for the supply of mechanical, hydraulic and electrical equipment for the generating stations at Castelo do Bode on the River Zezere and at Vila Nova on the River Cavado, and later, a contract was placed by the Companhia Nacional de Electricidade for the sub-station at Castelo do Bode, known as the Zezere Sub-station. More recently a contract has been placed with the same Group for the power station plant and equipment at Cabril, also on the River Zezere, which we shall be describing in due course.

The Castelo do Bode scheme was described in an article published in our May-June issue of 1950 (page 93) and we are now able to give technical particulars of the Vila Nova station, following a brief account in our August 1951 issue (page 307).

Arrangement at Site

The dam built across the River Rabagao at Venda Nova is more than two miles from the power station built at Vila Nova on the River Cavado, and the tunnel leading from the reservoir is lined with steel at the end where it connects with the valve at the head of the pipeline. This valve is 2·13 metres (7 ft.) bore, and is of the straightflow type. The self-closing of the valve is initiated by a paddle trip operated by excess flow. The pipeline, supplied and erected by the South Durham Steel & Iron Co. Ltd., is 2·4 m. (95 in.) in diameter at the top and tapers to 2·11 m. (83 in.) diameter at the bottom; the steel varies in thickness from $\frac{5}{8}$ in. at the top to 2 in. at the bottom. The pipeline ends in a distributing system which runs along the upstream side of the power house and connects with the inlets of the turbines.

The inlet valves, two for each of the three twin turbines, are also of the straightflow type, of 825 mm. ($32\frac{1}{2}$ in.) bore, and because of the high head have been constructed in cast steel.

The generating units are installed in the machine hall, illustrated in Fig. 2, which shows the ample dimensions. The control room is at one end and overlooks the entire floor space. On the upstream side the 11-kV and 33-kV switchgear rooms and cable galleries are situated. The 165-kV substation is on a level with the top of the power house, slightly upstream, and against the steep-sloping hillside.

The sets are started and stopped manually, but full control is centred in the control room. Synchronising takes place automatically when voltage and synchronism have been correctly adjusted.

Turbines

The three turbines are of the horizontal impulse type, with four jets, the twin runners being overhung from each end of the generator. The nominal rating at 395 m. (1,300 ft.) head is 36,000 h.p., but 39,000 h.p. is attained at the maximum head of 415 m. (1,360 ft.). The speed is 428 r.p.m.

The runners are cast in one piece, that is, with integral buckets, in stainless steel. The four inlet bends for each set have cast-steel nozzles, stainless-steel diffusers and spears having renewable stainless-steel points. A special feature of these turbines is that they can rapidly be brought to rest by means of a braking jet of water applied to the backs of the buckets. Each set has an automatic oil pressure governor, the actuator being gear-driven from the alternator shaft.

The generators are rated at 32,000 kVA at 0·8 p.f. and 11,000 V. They are provided with two bearings from which the runners are overhung at each end. The ventilation system is a closed circuit one with water-cooled air coolers mounted in the generator pit and constructed in four units to reduce withdrawal space.

Fig. 2. The machine hall housing three 32,000 kVA generating sets

The stator was built in two halves to facilitate transportation. The rotor is of the solid-disc type with tee-shaped slots into which the poles are keyed. The rotating parts are designed to withstand the maximum speed attained on runaway, that is, 793 r.p.m.

A separate exciter set is provided for each generator set, comprising the driving motor, main and pilot exciters and a flywheel to smooth out the field forcing peaks and to provide stored energy for maintaining the excitation should the generator voltage, and hence the driving motor supply via the unit transformer, collapse under fault conditions.

The 165-kV output voltage of the transformers is kept constant by automatic voltage regulation of the generator voltage, in the same way as at Castelo do Bode. CO_2 fire quenching equipment is provided.

Main Transformers

The main transformers for each set comprise a three-phase direct-connected group of single-phase units. Transport difficulties precluded the use of three-phase units. Each single-phase unit weighs 35 tons, or 23·5 tons when stripped for transport. Each group is rated at 30 MVA, having a ratio of 11/165 kV at full load (0·85 p.f.). The units are connected

Fig. 3. Outdoor air-blast circuit breakers

in delta on the lower voltage side and star on the 165 kV side, with the neutral point solidly earthed. Off-circuit tap changing and cooling arrangements are similar to those at Castelo do Bode.

Auxiliary Services

An auxiliary set, also driven by impulse turbine, is provided, but the low tension services are alternatively supplied from auxiliary transformers taking power from an external 30 kV system. The auxiliaries for each unit are supplied from a unit transformer. All 380 V circuit breakers are of the air break type.

Station Switchgear

The generators are connected directly to the transformers by copper bar running in horizontal and vertical ducts. Links and transfer bars are provided in these connections to enable any generator to be connected to any main transformer bank or to the water resistance test tank.

The main control board is of the vertical sheet steel cubicle type arranged on three sides of a rectangle. A desk type control board is centrally placed. The control room also contains the main relay board and metering boards. An additional cubicle gives alarm and indication for the intake gates at the dam and all other valves, with a mimic diagram having illuminated semaphore indicators. It is possible to close any valve in an emergency from this panel.

The station switchgear includes 33 kV-air blast circuit breakers in stonework cells. The 33 kV circuits connect to the supply from the nearby hydro-electric station of Ermal, and also supply the local houses. Ancillary equipment at the station includes the station batteries. A three-phase water resistance tank is provided for the full output of one set.

165-kV Outdoor Substation

The substation consists initially of three generator circuits, bus coupler, and outgoing feeder to Oporto with space for a fourth generator and a fourth feeder. Construction is in duplicate busbar arrangement with tubular conductors and interlocked off load selection, all being supported by post insulators on galvanised steel structures. The outgoing feeder spans the Cavado River.

Each circuit breaker is of the air-blast type, rated at 600 amp having a breaking capacity of 2,500 MVA at 165 kV, and—with the exception of the bus coupler breaker—complete with oil immersed porcelain clad wound primary type current transformers. The Oporto feeder breaker is equipped for single-phase and three-phase high-speed single-shot automatic reclosure with dead times adjustable from 15-60 and 10-20 cycles respectively. Relay equipment and selective control are mounted in the main control room.

Air is fed at 300 lb. per sq. in. through duplicate pipes from the compressor room on the floor below, the compressor itself storing at 600 lb. per sq. in. and having duplicate pumps, automatically controlled. Feeds from this compressor are also taken to the 30-kV switchgear and turbine governor through suitable reducing valves.

Station-type 165 kV surge diverters are included for each transformer group, and there is a three-phase 165,000/110/110-voltage transformer on the feeder for metering, distance protection, and synchronising, comprising three single-phase units line/ground connected star/star/delta. The generators have 11,000/110-voltage transformers for synchronising, etc., making use of delta/star phase shifting intermediate voltage transformers.

Main and Auxiliary Water Turbines and Turbine Inlet Valves	The English Electric Company.
Main and Auxiliary Generators	Metropolitan - Vickers Electrical Company.
Main, Auxiliary and Lighting Transformers	Metropolitan - Vickers Electrical Company.
Power Station and Substation Switchgear and Control Gear	The English Electric Company.
Disperser Valve, Portal Valve and Isolating Valve	The English Electric Company.
Pipelines and Distributing Piping	The South Durham Steel and Iron Company.
Power Station, Workshop and Valve House Cranes	Sir William Arrol and Company.
Water-flow Measuring Equipment	The English Electric Company.
Oil Purifying Equipment - -	Alfa-Laval Company and Stream-line Filters Limited.
"Mulsifyre" Fire Fighting Equipment	Mather and Platt Limited.

Water Power in Rumanian Electrification

A review of the role of water power in Rumania's ten-year electrification plan.

By JOHN CARDEW

PROVISION to utilise the country's waterways on a large scale is one of the most important aspects of a ten-year electrification programme undertaken by Rumania. This plan, launched in 1951, is estimated to result in an installed power of 2,600,000 kW, of which 835,000 kW, or over 30 per cent., will come from hydro-electric schemes.

On the basis of admittedly incomplete data, it has been estimated that Rumania possesses a total potential of 5,650,000 kW derivable from water power, with an average production of 27·2 billion kWh per annum. All Rumania's rivers flow directly or indirectly into the Danube. The Danube flows through Rumanian territory for a distance of about 500 miles, some 80 miles of the course being through relatively narrow passageways in the Carpathians where the banks are in many places 200 ft. high. Some of the Transylvanian rivers—the Somes, Cris and Mures—flow into the Tisa which crosses the Hungarian plain and runs into the Danube. Other important affluents of the Danube, on which hydro-electric projects are either under way or scheduled, are the Jiu, which breaks through the mountains in a rocky gorge and runs through a valley containing Rumania's largest coal deposits; the Olt, one of the longest rivers in the country; the Arges, into which the Dambovita, on which Bucharest is situated, flows; and the Ialomita, which passes through the Baragan corn-growing district. The swift-flowing Bistritza, on which the largest hydro project scheduled under the electrification plan is at present being constructed, joins the Siret which flows through Moldavia.

In 1946 a project for a giant power station at the Iron Gates, where the Danube flows in a gorge between Rumania and Yugoslavia, was discussed but came to nothing, although the potentialities were recognised to form an important source of hydro-electric energy which could be economically exploited. A total capacity of about 1,280,000 kW is estimated to be available, capable of producing 8·8 billion kWh in an average year.

Table I, which relates to 1950, gives the sources of electrical power in Rumania and shows the reliance placed on natural gas and oil and the meagre use made of water power.

TABLE I. SOURCES OF ELECTRIC POWER IN RUMANIA IN 1950

Natural gas	40·3 per cent.
Oil products	29·8 per cent.
High-grade coal	6·1 per cent.
Coal waste and low-grade coal ...	13·7 per cent.
Other fuel	2·1 per cent.
Hydro-electric stations	8·0 per cent.

In this year power stations were consuming annually 500 millon cu. m. of natural gas and 250,000 tons of oil products that were urgently needed for the chemical and other industries, and it was the heavy consumption of these valuable assets which first caused attention to be focused on the need for developing water power. In consequence provision has been made to more than double the capacity of plants by the end of 1955 and to increase them fourfold by the time the electrification plan is completed in 1960. During this period the situation is expected to be as shown in Table II.

Under the plan the average installed power for the entire country will increase from 2·53 kW per square kilometre, or 37·5 W per inhabitant, to 10·6 kW per square kilometre or 150 W per inhabitant. By the end of the ten-year period the consumption of oil products will have decreased to approximately 120,000 tons annually, which is less than half the present quantity, while that of gas will have dropped to something like 420 million cu. m.

Fig. 1. Dam under construction at the V.I. Lenin station

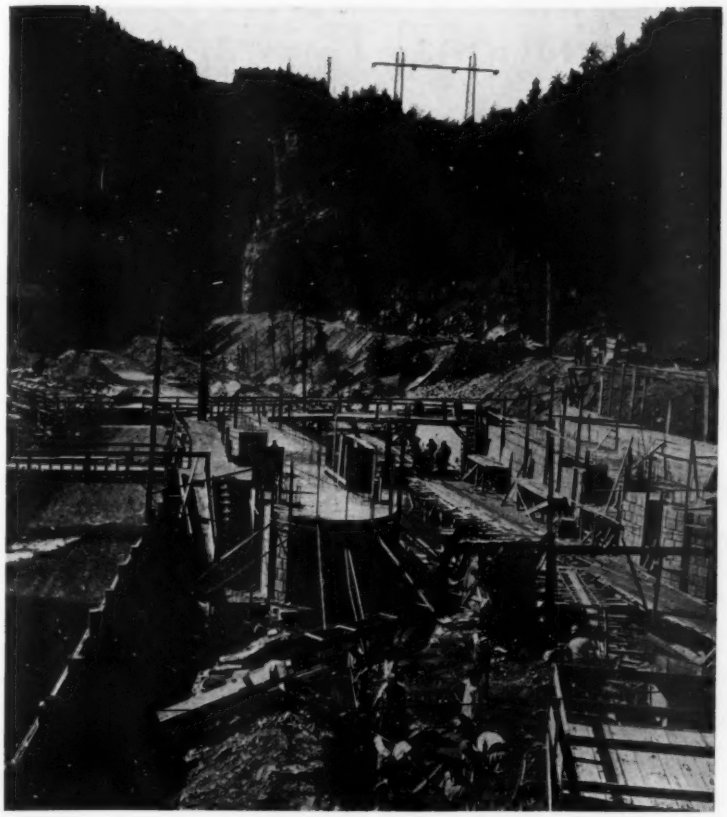


Fig. 2. Construction site at the Moroeni station

TABLE II. HYDRO-ELECTRIC POWER IN RUMANIA, 1950-60

	1950	1955	1960
	kW	kW	kW
Installed capacity .	740,000	1,700,000	2,600,000
Available capacity .	600,000	1,660,000	2,500,000
of which:			
Thermal	550,000	1,370,000	1,665,000
Hydro	50,000	290,000	835,000
that is:			
	%	%	%
Thermal	92	82·5	66·6
Hydro	8	17·5	33·4

Under the ten-year programme a total of 24 hydro-electric stations are to be built in various parts of the country and their combined capacity is estimated to amount to 764,000 kW, while an additional 20,000 kW will be derived from the harnessing of small rivers in local stations. Attention will be chiefly directed to large stations which, in addition to providing power, will also prevent floods and maintain water levels for irrigation and navigational works.

The largest project is to be situated at Bicaz, on the Bistritza, in north-east Rumania. It is designed to have a capacity of 210,000 kW and will produce about 430 million kWh per annum. The Bistritza flows through an important timber-producing region, which, however, is sparsely populated and ill-provided with good roads. Workers have had to be drawn from all parts of the country and the recruitment of many peasants has given scope for training them in industrial ideas—a fact which is regarded as especially important from the point of view of the future needs of Rumanian industrial expansion.

The scheme has involved the creation of a lake about 300 ft. deep and capable of storing a million cu. m. of water. The intake is situated 150 ft. below surface level, thus affording a substantial drawdown. At present the foundations are nearing completion and a concrete plant is being erected near the dam.

Other major hydro stations being built include one at Moroeni in the southern Carpathians and one at Raul-Mare to supply the Jiu valley, the Banat and south-western Transylvania. Dams are being erected in other areas where natural conditions are favourable for economic development. What is described as a provisional figure puts the potential storage capacity of dams which can economically be built at approximately 4,200 million cu. m. Construction will be chiefly confined to main waterways, such as the Isvorul Muntelui on the Bistritza, the Tunel dam on the Arges, the Bolboci on the Ialomita, the Vidra on the Lotru, the Prisaca Dornei on the Moldova and others on the Olt, Dambovita, Buzau, Putna, Somes, and Mures.

In rural electrification hydro-electric stations are to provide about half the power that will be required to electrify some 2,000 Rumanian villages in the course of the five-year plan. The basis for this programme is to be provided by small local stations with preference given to those that can utilise water power, special emphasis being placed on small river plants capable of affording 500 kW or more of installed capacity. It has been calculated that even smaller plants of this kind will ultimately aggregate 500,000 kW.

Fig. 3. One of the tunnel entrances at the site of the V.I. Lenin station

Minnesota International Hydraulics Convention

This Convention, which combined the fifth plenary meeting of the International Association for Hydraulic Research and the second separate meeting of the Hydraulics Division of the American Society of Civil Engineers, was held at the University of Minnesota in September. We summarise some of the papers having relevance to hydro-electric practice.

PART TWO

Density Currents

Of the seven papers given in this section, three related to density currents in reservoirs, three to those in estuaries, and one to laboratory studies supplemented by field investigations. Two of the papers on reservoirs described investigations in the United States, one being on the Tennessee Valley Authority system and the other on Lake Mead.

The first of these papers is entitled "Significant Effects of Density Currents in T.V.A.'s Integrated Reservoir and River System," by Albert S. Fry, M. A. Churchill, and Rex A. Elder, Tennessee Valley Authority. The Tennessee Valley Authority is operating an integrated system of 30 reservoirs on the Tennessee River and its principal tributaries. While collecting information on density-current flows for the solution of practical operating problems, the T.V.A. system has afforded what is in effect a large outdoor laboratory for density-current study. This paper presents some of these observations in relation particularly to their practical aspects in the operation of the T.V.A. reservoir system.

Water stored in large reservoirs on tributary streams thermally stratifies during the period from spring to autumn. Inflow moves through these reservoirs in the form of density currents due primarily to temperature differentials and secondarily to dissolved minerals and suspended sediment. Cold water released from tributary storage reservoirs into downstream reservoirs on the main stream causes induced density currents in those reservoirs.

In practical system operation, T.V.A. found that density-current flows were important to industrial water use, stream pollution, recreation, municipal water supply, and steam-plant condensing water.

Water temperatures for use of industry are affected by density flows through reservoirs. Sources of water supply may be polluted by flow patterns set up through density currents. Portions of main reservoir bodies may or may not be safe for swimming, depending upon density-current flows. Reservoir embayments may be unfit for swimming because of pollution being carried upstream in the embayments by subsurface flows. Of particular significance is the part played by density currents in serving as the means for providing condenser water of suitable temperature at T.V.A.'s large Kingston steam plant.

Operation of water-use projects for hydro-power development to meet fluctuating load demands results in unsteady density-current flows which may be important in situations influenced by density currents.

The second paper, "Density Currents in Lake Mead," was contributed by C. S. Howard, U.S. Geological Survey. Density currents have been observed in Lake Mead since the early days of storage. Observations made by the Bureau of Reclamation show movement of these currents into and through the reservoir, sometimes as overflows, sometimes as interflows and underflows. Many of the underflows carry fine material consisting chiefly of particles which, in the natural condition of flocculation, have settling diameters less than 20 microns (0·020 mm.). Some of this fine material from the beginning of storage has accumulated throughout the lake, even reaching the upstream face of Hoover dam. On December 30, 1952, the top of the sediment at the dam was at elevation 728 ft., representing approximately 100 ft. of deposited material. In the first 14 years of storage over 1,420,000 acre-feet of sediment were deposited in Lake Mead, of which about 65 per cent. (by volume) consisted of material transported by density currents.

An interesting paper on French investigations was contributed by A. Nizery and J. Bonnin, Électricité de France, entitled "Systematic Observations of Density Currents in a Hydro-Electric Reservoir." The management of Études et Recherches de l'Électricité de France has undertaken systematic observations of density currents in the Sautet reservoir on the Drac River. The observations were made during 1951-52 and comprised measurements of turbidity, temperature, and velocity recorded simultaneously at a point.

The turbidity was measured by means of two photoelectric cells, the temperature by thermoelectric couples, and the velocity by either a current meter or a thermal method. Only six density currents or related phenomena were investigated because of the difficulties involved in obtaining accurate measurements, particularly in the case of low velocities. The relative smallness of the reservoir, where the observed phenomena are ten to twenty times more ephemeral than at Lake Mead, constituted another disadvantage.

The results were as follows. The flow pattern in which the temperature effect is often preponderant occurs under various conditions. Contrary to the observations made at Lake Mead over a period of nearly twenty years, the present observations have not established that the upstream pattern of the density current persists up to the dam, and it became possible to prove in a given case the influence of the shape of the section on the propagation of the turbidity

wave. The reasons for the disparity of the density current in the downstream part of the reservoir are not yet fully elucidated and will be the chief object of future researches.

The paper "Some Observations on Density Currents in the Laboratory and in the Field" was presented by Bata Geza and Knezevich Bogich, Serbian Academy of Sciences, Yugoslavia. In the experimental part of this study, the influence of the variation in viscosity of the superposed stratum on the resistance of the underlying, heavy stratum was examined as well as the relation between resistances and velocity distributions in both strata. In the section on laminar flow it was shown that the resistances vary within the limits $\frac{196}{Re} < \lambda < \frac{236}{Re}$ at the tenfold difference of the viscosity of the upper liquid. Equations are given for determining the thickness of the "entrained" layer, but the phenomenon of disturbance at the contact of the entrained and retrograde layer of the superposed stratum has only been described. In the case of turbulent flow, the same result is obtained whether the resistance coefficient λ is obtained from the velocity-diagram area or from the diagram $\lambda = f(Re)$. The resistance coefficient at the interface amounts to $\lambda_i = 0{\cdot}010 - 0{\cdot}020$.

Investigations in the Groshnitza and Treska reservoirs have shown that several factors considerably complicate the application of the laboratory results obtained so far in analysing the motion of density currents in reservoirs. These factors are as follows: gradual decrease in the concentration of the underflow, non-uniform turbidity distribution in the verticals, determination of the volume of the captured ballast liquid, unsteady waves, and temperature effects.

Papers on density currents in estuaries included "The Role of Density Currents in Estuaries," by Henry Stommel, Woods Hole Oceanographic Institution, United States, "Density Current Problems in an Estuary," by Tokuichi Hamada, Transportation Technical Research Institute, Japan, and "Theoretical Considerations on the Motion of Salt and Fresh Water," by J. B. Schijf and J. C. Schönfeld, Rijkswaterstaat, Netherlands.

Air Entrainment by Flowing Water

No less than 12 papers were presented in this important section.

In "Some Prototype Observations of Air-Entrained Flow," V. Michels and M. Lovely, of the State Rivers and Water Supply Commission, Australia, recount some investigations they made in connection with the design of a chute spillway for the Eildon dam. This will have an overfall section 120 ft. high to a fixed ogee crest provided with three undershot vertical-lift gates 20 ft. high with a 65·6 ft. opening. The water will discharge into a concrete-lined chute 1,300 ft. long, having successive bed slopes of 0·075 and 0·10. The designed overflow is 120,000 cusecs, and velocities in the chute will range from 80 to 100 ft. per sec.

In a preliminary section of the paper the authors suggest a classification of the various types of air entrainment and their associated flow conditions, as follows: rippled flow, no entrainment; choppy flow, slight and sporadic entrainment; scarified flow, an air-water mixture in a relatively thin layer on the surface of a stream; emulsified flow, a general, deep and continuous emulsification; ebullient flow, a violent air-water mixture occurring as a boil on the surface; spraying flow, a water jet discharging to atmosphere; and separation flow, involving reduction and instability of pressure.

It is suggested that the following conditions may have to be met for air entrainment to occur: (1) turbulence may have to exceed a certain minimum beyond which water particles can overcome surface tension and leave the surface; (2) the speed of these particles relative to the surrounding air may have to exceed a certain minimum; (3) for entrainment to continue downstream, the turbulence, and hence the energy gradient, should remain constant or should increase.

Reference is made to the work of Lane, Hickox, Hall and Pavel, according to which the following conditions must be fulfilled for entrainment to occur: (1) the flow velocity should exceed a certain minimum stated to range from 10 to 20 ft. per min.; (2) turbulence caused by boundary-layer development should extend throughout the whole depth of flow; (3) for uniform flow the channel bed slope should exceed a certain minimum value. Arguing from the second of these premises it is considered that since the slope of the energy gradient is related directly to the degree of turbulence in the stream it is reasonable to define the lower limit of turbulence necessary to cause air entrainment as a function of the energy gradient.

Discrepancies and gaps in the published literature made it impossible to forecast with certainty whether entrainment would occur on the Eildon chute spillway, and prototype observations were therefore carried out on Glenmaggie dam and on Werribee weir. The former is a concrete gravity structure with a spillway section 370 ft. long and 50 ft. high from apron to ogee crest. The training walls have an average height of 5 ft. and piers 3·6 ft. thick are spaced at 28 ft. centres along the crest. Werribee weir is a concrete overfall weir 12 ft. high. Test results are given in

Table I. Test Results for Glenmaggie Dam and Werribee Weir

Location	Head on Crest	Commencement of Entrainment		Ratio L/D	Calculated Unit discharge	Calculated Velocity Commencement of Entrainment
		Measured distance to	Calculated depth at			
	ft.	L ft.	D ft.		q cusecs.	V ft. per sec.
Werribee	1·0	23	0·147	156	3·20	21·8
	2·5	48	0·347	138	13·35	38·5
	4·0	73	0·552	132	28·3	51·2
	8·5	97	1·53	64	95·5	62·2
Glenmaggie	0·60	8	0·11	72·7	1·50	13·6
	0·78	10	0·136	73·5	2·20	16·4

Table II. Test Results for Big Hill Chute and Spring Gully Race

Chute	Bed slope	Discharge cusecs.	Measured uniform depth ft.	Hydr. Radius R. ft.	Pavel's minimum slope for partial emulsification	Calculated velocity in chute V ft. per sec.
Big Hill - -	0·0725	23·8 26·5	0·50 0·53	0·37 0·39	0·094 0·093	16·0 16·5
Spring Gully -	0·092	16·0 21·0	0·54 0·62	0·34 0·38	0·095 0·094	15·7 17·0

Table I, from which it will be seen that emulsified flow commences at a distance which increases with a rise in head on the crest. This is held to be the main evidence in favour of the theory that this type of entrainment does not occur until the thickness of the turbulent boundary layer coincides with the depth of flow.

According to Pavel's method of calculation no entrainment should occur on the Eildon chute, but to check this tests were made on the Big Hill and Spring Gully chutes, both being over 400 ft. long, of smooth concrete, with smooth entry conditions and provided with standard weirs. Big Hill chute is of rectangular cross section with a 3 ft. wide bed, and Spring Gully has a semicircular invert of 2 ft. radius. Results are given in Table II.

The authors then consider formulae for turbulent boundary-layer thickness along a flat plate under zero pressure gradient, and suggest the following empirical formula which agrees closely with the results given in Table I if suitable constants are chosen.

$$\delta = \frac{S \cdot q^{1/12}}{157{\cdot}7}$$

where δ is the thickness of the turbulent boundary layer and S is the distance from the leading edge.

The following conclusions are drawn from these studies:—

The design of channels carrying high-velocity flow lends itself to treatment in two broad phases: (1) flow in long chutes where boundary-layer turbulence extends throughout the depth of flow for most of the channel length and (2) flow in relatively short chutes where such turbulence may not extend to the surface of the flow at all. Chutes of the first type are in general of relatively small cross section carrying comparatively small quantities of water for power or irrigation purposes, whereas ogee spillways for dams are representative of the second type.

If Pavel's results based on model experiments are applicable to prototype channels, then the first step in design of chutes is to determine on the basis of the slope of the energy gradient, whether entrainment will occur and whether it will be associated with scarified or emulsified flow. Then, in the case of spillways, an estimate of the distance to start of emulsified air entrainment can be made on the basis of Hickox's data and the above-mentioned results. In many cases it will probably be found that general air entrainment will not occur on the spillway face for unit discharges above some figure considerably less than the design discharge. Training-wall heights designed high enough to enclose clear flow at the design discharge, may then be sufficient to contain air-entrained flow at the lower discharge. In any event, local air entrainment along the side walls occurring at all flows may be neglected in the design, as little or no increase in depth occurs there.

In chutes sufficiently long for air entrainment to occur over most of the length, flow depths can be calculated by either Hall's or Pavel's method and, at the worst, an approximate solution can be obtained.

In the case of the Big Eildon spillway it was assumed, on the evidence of the last test on the Glenmaggie overfall, that air entrainment would commence on the chute near the end of the vertical curve connecting overfall and chute. The observations on the Big Hill and Spring Gully chutes, though yielding results in agreement with Pavel's work, were not considered sufficiently conclusive to justify design according to his criterion and the chute was designed for air entrained flow throughout its length.

Laboratory studies of air entrainment in an open channel are recorded in a paper "Experimental Studies of Air Entrainment in Open Channel Flow" by Lorenz G. Straub and Owen P. Lamb of St. Anthony Falls Hydraulic Laboratory. A rectangular channel is in use capable of being set at any angle from horizontal to vertical. It is 18 in. wide, has an effective length of at least 45 ft., and has a wetted surface of painted steel. Air concentration at any point is measured by the electrical resistance of the air-water mixture between two small electrodes, the instrument being calibrated direct in percentage air concentration C. Velocity is measured by a diesel-type injector in conjunction with an electronic timer having an accuracy of about 1/100,000 sec.

In discussing the nature of the flow the authors point out that the conception of layer flows is erroneous, as experiments show conclusively that air concentration increases continuously (although not to a straight-line law) with elevation above the flume bottom. The thesis that aeration becomes incipient where the turbulent boundary layer from the flume bottom intersects the water surface is regarded as valid. For any given section, slope, roughness and discharge, a condition of normal aeration can be attained in which a balance is maintained between the amount of air insufflated and the amount released. At the water surface an air current is induced by the moving water. This may be expected to cause a velocity drag in the air-water mixture in the region of the surface, and investigations show that this drag actually exists.

With the rough surface characteristic of aerated flow a practical difficulty is to determine the water surface. This has been arbitrarily defined as the elevation z at which $C = 0{\cdot}95$, and it has been found possible to correlate results on this basis. It was found that the flume was wide enough to ensure two-dimensional flow for several inches on either side of the flume centreline, and no asymmetry was found in any condition of aeration.

A series of tests was run at various discharges at a constant flume angle and also a series at constant discharge and various flume angles. The results are

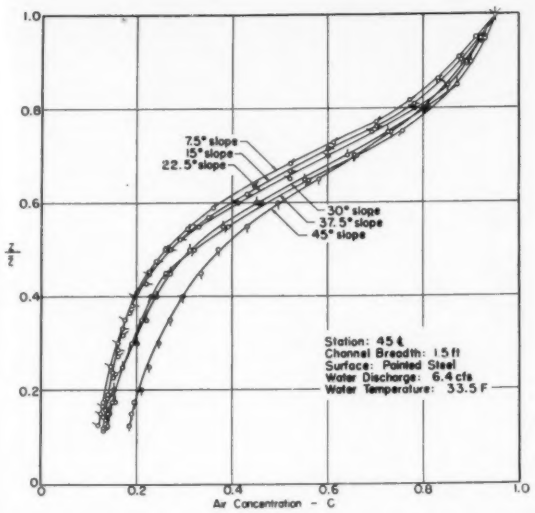


Fig. 6. Measured air concentration values in full aerated flows at various flume angles with constant discharge

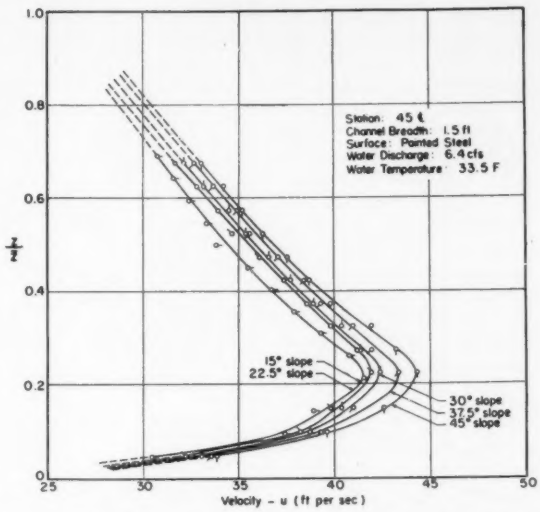


Fig. 7. Measured velocities in fully aerated flows at various flume angles with constant discharge

tabulated in Table III and the curves given in Figs. 6 and 7 show the characteristic shapes obtained. A run was also made in the non-aerated condition at a flume angle of 7·75° and a measured discharge of 7·1 cusecs.

An increase in mean air concentration with increasing flume angle is shown in the table for a constant water discharge where the flows were established as having a complete normal aeration. However, the spread of mean air concentration values is quite small and suggests that the bulking of the flows is not particularly sensitive to slope changes alone. Since the runs at varying discharges were not all established as reaching a condition of normal aeration, the respective mean air concentration values are not comparable on the basis of different discharges. A comparison of the slope and discharge for the non-aerated run with the slope and discharge of the normal aerated run on the $7\frac{1}{2}°$ flume angle shows very little difference between the flow variables, yet a bulking of the flow equivalent to a mean air concentration of 0·39 and considerably higher velocities were measured in the aerated flow.

It is possible that a slight retardation of the flow at the inlet might have been sufficient to carry the one flow past a critical where it would then tend to become aerated, but the similarity of traverses at the several downstream stations showed no tendency of the flow to revert to a non-aerated condition.

Defined flow depth z experienced very little change with slope for the various runs at constant discharge. Within the narrow range of the reported experiments, any tendency to increase the section by greater bulking appeared to be compensated by a further increase in velocity so that flow depth remained nearly constant.

The relations between slope and velocity in uniform open channel flow in most common usage are empirical modifications of the semi-rational Chezy equation. The Manning form of the equation is familiar to the enginering profession and has been widely accepted for design purposes in conventional mild slope channels. However, doubts have persisted as to the validity of any of the conventional expressions in channels of steep gradients or in cases where high velocities can be expected. With aeration also a consideration, the problem of predicting mean velocity at steep gradients becomes much more complicated.

Earlier authors on the subject of air entrainment have proposed computed values of the hydraulic radius to be used with conventional n values. In one case, the computed value of hydraulic radius is based on an area and the wetted perimeter of a computed shallower section occupied by water alone, and in the

Table III. Flows with Normal and Partial Aeration on Painted Steel Surface

Flume Angle	Defined Surface Elevation	Measured Water Discharge	Unit Discharge	Integrated Water Discharge	Mean Velocity	Mean Air Concentration	Remarks
Θ	z	Q_w	$q_w = \frac{2}{3} Q_w$	q_w	U	c	
degrees	ft.	cusecs.	cusecs.	cusecs.	ft. per sec.		
$7\frac{1}{2}$	0·2292	6·4	4·267	no velocity traverse	—	0·390	Normal aeration
15	0·2188	6·4	4·267	4·60	35·38	0·406	Normal aeration
$22\frac{1}{2}$	0·2188	6·4	4·267	4·48	35·93	0·430	Normal aeration
30	0·2135	6·4	4·267	4·31	36·25	0·443	Normal aeration
$37\frac{1}{2}$	0·2083	6·4	4·267	4·34	37·54	0·445	Normal aeration
45	0·2032	6·4	4·267	4·27	39·79	0·472	Normal aeration
15	0·2656	9·6	6·40	6·35	36·22	0·340	Partial aeration
15	0·3229	12·8	8·53	8·59	36·34	0·268	Partial aeration

other case the computed value is based on the area of the shallower section of water alone and a wetted perimeter of the full flow section. Checking these expressions with the data presented in Table III, n values are obtained which show no agreement with the n value obtained experimentally for uniform flow in the flume with no aeration.

Applying the Manning equation to the experimental results the following results were obtained:—

Flume Slope	15°	22½°	30°	37½°	45°
Mean Velocity by Manning Formula, V ft. per sec.	23·1	26	28·1	29·8	31·2
Mean Velocity measured (from Table III)	35·38	35·93	36·25	37·54	39·79

By comparing these predicted mean velocities from the Manning equation with the measured U from Table III it can be seen that in all cases the predicted velocity is too low.

A somewhat similar investigation is in progress at the Laboratoire Dauphinois d'Hydraulique Neyrpic, and is described in a paper "Air Entrainment in Steeply Sloping Flumes" by G. Halbroun, R. Durand and G. Cohen de Lara, but it is considered that the work has not yet progressed far enough to enable general conclusions to be drawn.

On the general question of type of flow the authors state that Schoklitsch's conclusion that aeration occurs above a certain critical velocity of some 4 m. per sec. is refuted by experience, for when the head on a dam spillway increases, the point at which entrainment commences moves down the face. It is contended that entrainment can only occur under conditions of turbulence, when water particles receive sufficient velocity normal to the water surface to escape from the main current. This agrees with the theory that the critical point is that at which the boundary layer reaches the free surface.

The reason why white water occurs on the actual structure but not on a scale model can be understood by considering the effects of scale. On a $1/\mu$ scale model the kinetic energy of a droplet is $1/\mu^4$ of that on the prototype whereas the surface tension is $1/\mu^2$. Hence it is easy to see why the water surface will only be bumpy on the model.

The laboratory investigations are being carried out on an adjustable-slope platform, 53 ft. long by 3 ft. wide, on which flumes of different widths can be placed. For the present studies a flume 0·5 m. wide is being used, and the results recorded relate to a single flume slope of 14°.

It was first necessary to establish a condition of uniform flow, and to determine this the velocity and air-concentration distribution curves were ascertained at two stations about 7 ft. apart and superimposed. As originally arranged the channel was found to be too short, but the required condition was achieved by placing a metal grid immediately below the supply sector grid and by artificially roughening the wetted surface of the flume.

Air-concentration curves against depth for six different discharges are given in Fig. 8. All of these curves present a break corresponding to a concentration value of about 60 per cent. It may be assumed, as mentioned also by Dr. Straub, that this break corresponds to the passage from the emulsion zone (air bubbles in water) to the ejection zone (drops of water in air). It has indeed been mentioned that the air bubbles carried up into the upper part of the emulsion zone are spherical and that they all have practically the same diameter. The maximum degree of compactness of such a sphere system is also about 60 per cent. If the air concentration tends to rise above the value of 60 per cent., the bubbles which are squashed up against each other unite and the water which surrounded them changes into drops. This is the passage from air bubbles in water to drops of water in air.

An attempt was made to determine directly the depths corresponding to the boundary surface of the emulsion zone and of the droplet zone. In view of this, the data given by a static pressure tapping placed in the flow were measured by a micromanometer. In the droplet zone only the atmospheric pressure was measured. The curve obtained by investigations along a vertical line, therefore, also presents a break at the passage from one zone to another. The corresponding depths were seen to be identical to those for which the air concentration is 60 per cent. It thus seems to have been thoroughly proved that, for the 14° slope which was investigated, the passage from the emulsion zone to the droplet zone always corresponds to a concentration of about 60 per cent., whatever the discharge value may be.

A third paper recording experimental work on steep flumes was presented by Michele Viparelli, of Naples University, under the title "The Flow in a Flume with 1 : 1 Slope." It is concluded that near the bottom of fast water flow there is a layer of water with small air bubbles which follow considerably the fluctuations of the turbulence. The velocity distribution follows the laws of the theory of the turbulence. The depth of this layer increases with the water discharge. In the upper layers, on the contrary, there is an air current in which fast water drops move, retaining the velocity

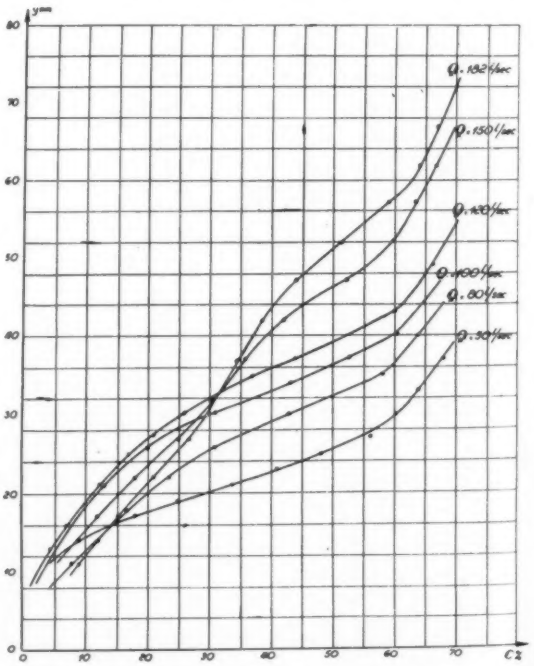


Fig. 8. Air concentration distribution curves for various water discharges at a flume angle of 14°

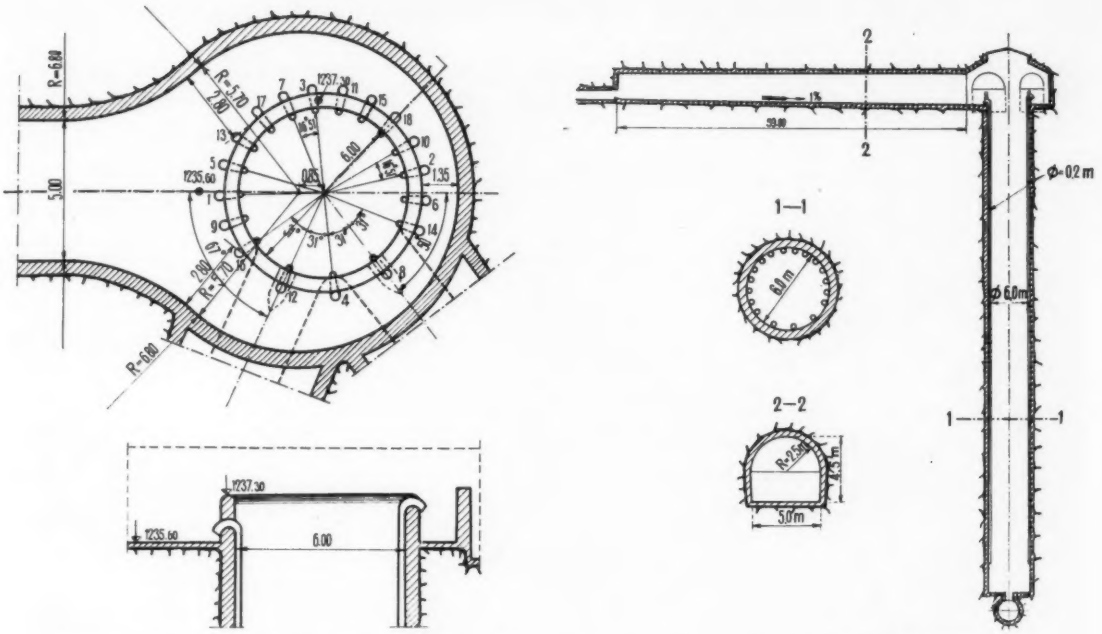


Fig. 9. Jelavska creek inlet to the Mavrovo pressure tunnel, showing multiple-syphon system

of the layers of the water and air mixture from which they come. The water drops are distributed according to the law of normal probability.

A further paper on air entrainment in steep chutes was presented by Ante Frankovic, of Vodogradbeni Laboratory, Yugoslavia, entitled "Head Loss and Air Entrainment by Flowing Water in Steep Chutes." It is predominantly mathematical.

Another predominantly theoretical paper on this subject is "Entrainment of Air in Flowing Water and Technical Problems connected with it" by V. Jevdjevich and L. Levin, Avala Hydraulic Laboratory, Yugoslavia. This paper, however, contains an interesting reference to a method of feeding a supplementary supply to a pressure tunnel through a vertical shaft with minimum air entrainment. In many cases this water is fed to the pressure system through a syphon, but as the inflow is usually variable the syphon operates intermittently and draws air at each cycle. The method proposed is to use a battery of small-diameter syphons having their inlets at successive levels so that the number of syphons in operation depends on the level of the inflow. The quantity of air induced when a syphon commences to operate is small and readily escapes through the main vertical shaft, which has a cross-sectional area greatly in excess of the syphon. This system is being used for the Jelovska Creek inlet for the Mavrovo power stations, and drawings are reproduced in Fig. 9. The maximum discharge to be handled is 4·5 cu. m. per sec., and the installation comprises 18 syphons of 0·2 m. diameter. The vacuum in any syphon does not exceed 6 m. The vertical shaft acts also as a surge shaft. The paper also gives brief details of experiments on tangential inlets to vertical shafts.

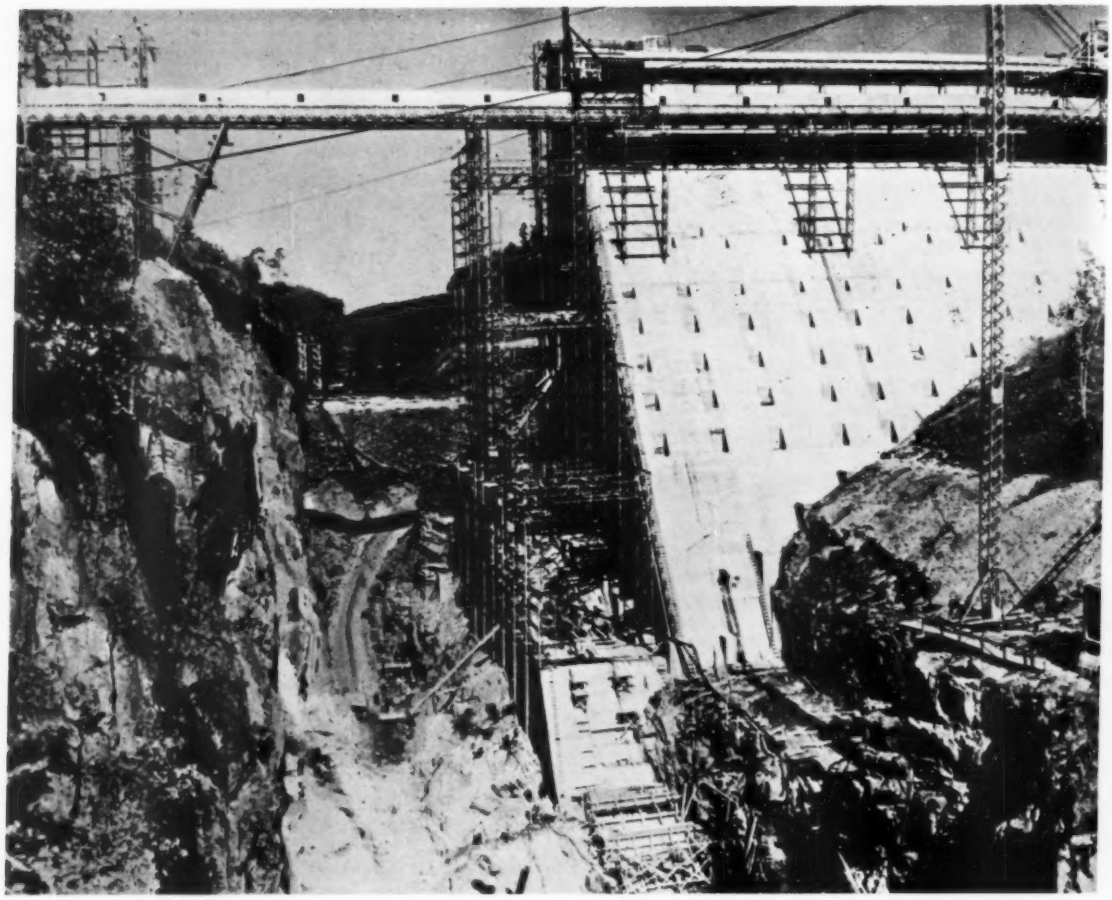
(To be continued)

Ten Years of Scottish Progress

Mr. T. Lawrie, General Manager of the North of Scotland Hydro-Electric Board, said in Dundee recently that during the ten years of the Board's existence 17 hydro-electric power stations, totalling 398,000 kW, had been completed; 24 power stations, totalling 465,000 kW, were in course of construction or preparing for construction to begin, and about 15 were at various stages of surveying and preliminary investigation. The average productive capacity of these developments in units of electricity per annum was as follows: power stations already in operation (including the prewar Grampian stations), 935 million kWh; schemes on which work was in progress or about to begin, 1,435 million kWh; schemes in course of promotion and survey, probably 800 million kWh. These figures might sound large but so great was the growth of demand for electricity in the Board's supply area that the large steam-generating stations in Dundee and Aberdeen had still to be operated at a high level although much of the generating plant in them was obsolete and heavy on coal. In 1952, 300 million kWh were produced by steam and 210,000 tons of coal were burned in the process. Much coal, however, was already being saved by water power. The present hydro-electric production was equivalent to 600,000 tons of coal per annum, and by the end of the next ten years this saving should be trebled or quadrupled.

In ten years' time the schemes now under construction should all be operating, a number of those under survey and preliminary examination should be completed, too, and further developments were likely also to be under way.

Bailey Bridging for Hydro-Electric Work



Bailey formwork in use for the Tunnel dam under construction by the Hydro-Electric Commission of Ontario

The accompanying photograph of one of the dams under construction of the Hydro-Electric Commission of Ontario shows the extent to which Bailey bridging is now used in hydro-electric construction. We have previously described the use of Bailey equipment to build the construction bridges across the dam sites on the Glen Affric scheme in Scotland, but in the present instance not only the construction bridge but the whole of the formwork has been built from Bailey components. The Hydro-Electric Commission of Ontario has adopted Bailey bridging as a standard method of construction, and recently saved nine months on a three-year dam contract by its use.

An obvious use for this equipment is for the construction of access bridges. An example of the punishment that the equipment can survive is provided by an access bridge that was built in conjunction with the Sir Adam Beck No. 2 station at Niagara across the tailrace of one of the Commission's existing stations. This bridge was caught in a severe ice jam and subjected to heavy pressure but was found to be completely undamaged after the jam had broken up.

The use of Bailey bridging for the rapid construction of emergency bridges—for instance, when a permanent bridge has been destroyed by flood—is too well known to need emphasis, but the use of this equipment for permanent construction may not be so widely appreciated. Nevertheless, many permanent structures built on this system are in existence in various parts of the world.

Other uses that have been found are for the erection of buildings and hangars for power shovels and other heavy civil-engineering equipment, and for the construction of temporary or permanent dykes.

Thos. Storey (Engineers) Limited, Stockport, who hold the world licences for the manufacture and sales of Bailey components, are today selling £1 million worth of this equipment each year, of which over 90 per cent. is for overseas markets. Large consignments have been delivered to the Snowy Mountains Hydro-Electric Authority and to the Hydro-Electric Commission in Tasmania.

50-Ton Compaction Roller

According to *New Zealand Engineering*, C. W. F. Hamilton & Co. Ltd., Christchurch, New Zealand, have built the largest earth-rolling machine yet used in the country.

The compaction roller consists of four or six welded steel weight boxes each mounted independently on a heavy-duty wheel and pneumatic tyre. Freely suspended inner weight boxes oscillate round a tail beam and follow the undulations of the ground, ensuring maximum pressure being brought to bear evenly over rough surfaces without the bridging of hollows. The closely spaced wheels are capable of as much as 12 to 14 in. variance in height without loss in compaction efficiency. To suit working conditions and available tractor power, two extra weight boxes can be employed, increasing the total loaded weight from 50 to 75 tons. The tractor horsepower required varies between 130 and 150. Unit construction simplifies shipping and provides easy servicing of tyres and wheels.

Three of these machines have been purchased by the New Zealand Ministry of Works for use on the earthfill dam at Whakamaru.

New Kent Flow Meter

Fig. 1. Kent "Commander" class "KU" flow indicator-integrator-recorder and pressure recorder

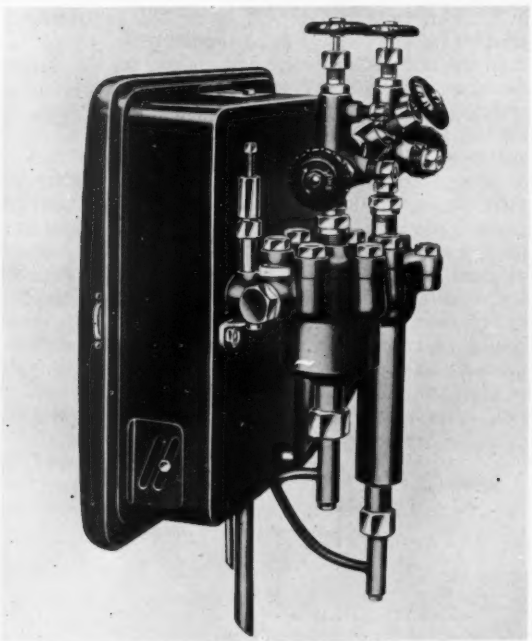


Fig. 2. Back view of the "KU" meter showing the mercury chambers and control head

George Kent Limited, Luton, England, have just introduced the first of a new series of standardised instruments, to be known as the "Commander" class. This standardisation will embrace the "presentation" mechanism, i.e., the case and front mechanism, including recording, integrating, indicating, and automatic control equipment. By this means spare parts for the meter fronts will be interchangeable irrespective of the functions of the individual meters, and the variety of spares that must be held in stock is thus minimised. Furthermore, a panel of these instruments, in spite of the variety of functions that may be measured, presents a neat and uniform appearance.

The first instrument in the new series is the "KU" flow meter depicted herewith. It is of the mercury U-tube type with forged steel mercury chambers designed for maximum working pressures of 2,000 and 250 lb. per sq. in. on the upstream and downstream legs respectively. A series of interchangeable upstream chambers and U-tubes, which can be changed on site, enables any one of six ranges to be chosen having maximum differential pressures from 25 to 600 in. w.g. (air-on-mercury basis). An adjustable throttle valve is fitted to the downstream leg to damp out the effect of pulsating flows.

The movement of the float is transmitted through a standard control head to the "presentation" mechanism, which can accommodate up to two pens (one for pressure measurement by bourdon tube) and a pointer. The integrator is a separate unit and may be driven either electrically or mechanically.

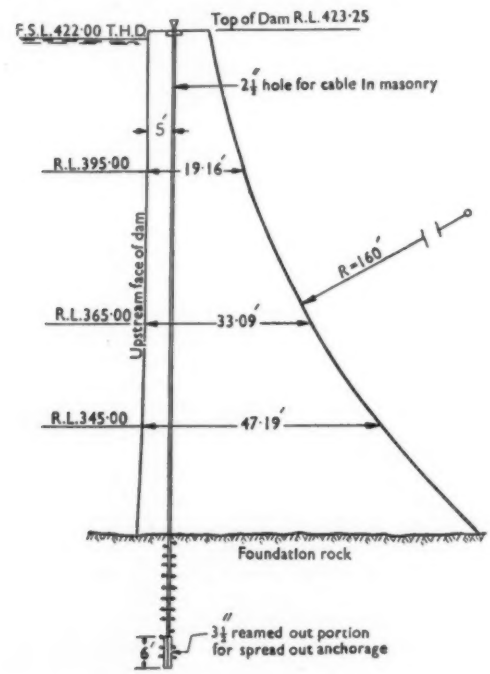
The case acts only as an envelope for the mechanism, which is mounted on a separate plate. Unified screw threads and spanner-flat sizes have been used throughout the instrument. The instrument can be panel, wall or post mounted.

Abstracts from the World Technical Press

Strengthening of Masonry Dams

The various methods applied to the strengthening of masonry dams are described and reviewed. The need for such strengthening may arise for reasons such as: (1) increase of storage capacity, as at Asswan on the Nile and a number of U.S.A. structures; (2) construction in stages in order to reduce the initial outlay, with subsequent and repeated heightening, as at Ross dam, U.S.A., constructed in 1940, and raised twice, in 1945 and 1951: (3) need for repairs, to check deterioration or improve stability, as at Tansa dam, India, completed in 1892. Instances are given of dams in India and other countries, either already strengthened or earmarked for strengthening.

In the concluding section of his article, the author discusses the methods adopted: earth back at non-spillway sections, additional masonry, dowel bars, or loading in a way similar to prestressing. The diagram appended shows the application of the Coyne method of prestressing to the Tansa dam; this consists fundamentally in drilling 2 in. or larger holes from the crest of the dam down to a depth of 25 to 35 ft. into the foundation rock, and in lowering a special pattern of steel rope into these holes. The bottom ends of the ropes are firmly grouted in the rock, and the top ends fixed on the crest in ferro-concrete or cast-iron heads which are jacked up by means of hydraulic jacks so as to create the necessary stress in the body of the dam. When the loading tests have been carried out, after about a year, the holes are ultimately grouted with cement to protect the ropes from rusting. In the case instanced stressing is intended to reach 70 metric tons per rope, which should prove adequate to eliminate tensile strength in the structure. (K. L. Rao, Director of Designs C.W. & P.C., New Delhi, *Irrigation & Power*, Vol. 10, No. 1, Jan. 1954, p. 49, 19 pp., 21 ff.)



Method of strengthening Tansa dam

Capacity Limit of Waterwheel-driven Alternators

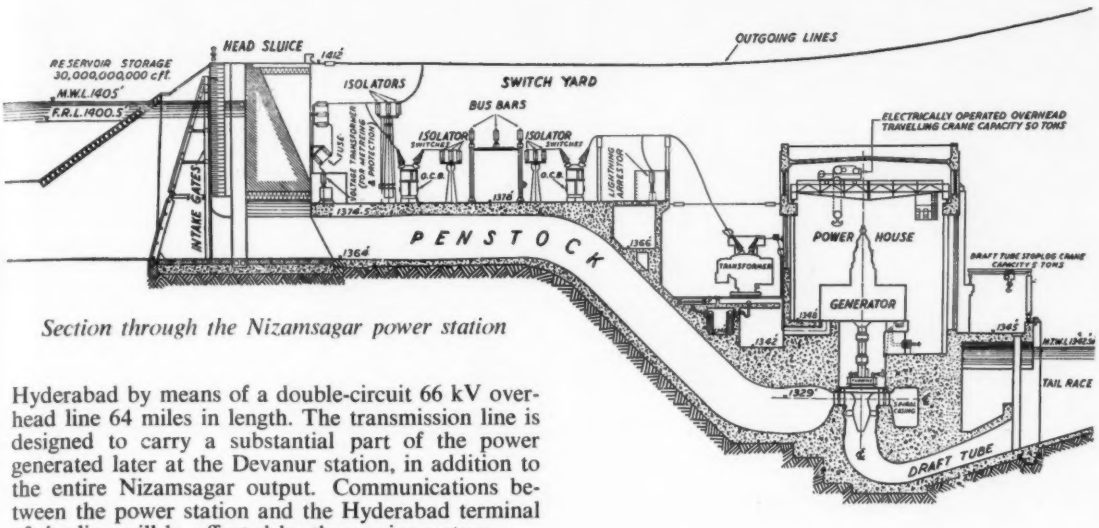
The increasing capacity of these alternators since the beginning of this century is reviewed and discussed. A typical example of such an increase is given at the outset: the Albula plant of the Zurich Corporation, equipped in 1907 with eight 2,500 kVA horizontal-shaft alternators running at 600 r.p.m., and re-equipped in 1945 with two 14,000 kVA vertical-shaft units running at 500 r.p.m. In this instance, in spite of a capacity increase of 8,000 kVA, the aggregate weight of the alternators has been reduced from 210 metric tons (10·5 kg/kVA) to 138 metric tons (4·9 kg/kVA), while efficiency at full load rose from 92 to 96·3 per cent. The following are further discussed: rotor design in relation to speed, type of the driving turbine, windings, cooling and exciters. Proceeding from the example of the slow-running 108,000 kVA Westinghouse alternators at the Grand Coulee plant, which run at 120 r.p.m. in normal operation, the runaway speed being about 220 r.p.m., it would seem that in the case of alternators operating at medium and slow speeds, turbine manufacturers have free scope to build as powerful machines as they desire, especially if they follow the American tendency, and are satisfied with moderate runaway speeds. The author concludes that a decision on this point must be guided by other considerations such as operating requirements and the necessity of having available an adequate standby power. (Jean Schneider, manager of Lausanne office of Oerlikon Works, *Bulletin Technique de la Suisse Romande*, Vol. 79, No. 11-12, 13.6.53, p. 251, 4 pp., 9 ff.)

Nizamsagar Hydro-Electric Scheme, India

The Nizamsagar power station constitutes the first phase of hydro-electric development on the Manjira River, a tributary of the Godavari, the second phase being the Devanur project. The Nizamsagar reservoir, completed in 1929, has a storage capacity of 29,700 million cu. ft.; the power station is situated below the head sluices and utilises a head varying between 65 and 35 ft., according to the fluctuations of level in the reservoir, combined with the three drops in the first 3,000 ft. of the irrigation channel.

Civil-engineering works comprise the power-house buildings and the administrative block, the penstocks, draught tubes, tailrace, approach roads and residential quarters; there will be two reinforced-concrete penstocks of rectangular section to each generating unit, and each penstock will be connected with one of the head gates. The spiral casings and draught tubes, the floors and roof of the power-house building, as well as the beams carrying the tracks of the travelling crane, are also of reinforced concrete.

The generating plant consists of three vertical-shaft Kaplan turbines directly coupled to 11,000 V a.c. generators each rated at 5,000 kW; the main transformers will step up to 66,000 V for transmission to



Section through the Nizamsagar power station

Hyderabad by means of a double-circuit 66 kV overhead line 64 miles in length. The transmission line is designed to carry a substantial part of the power generated later at the Devanur station, in addition to the entire Nizamsagar output. Communications between the power station and the Hyderabad terminal of the line will be effected by the carrier system.

The Nizamsagar plant has been designed to work in conjunction with the Devanur scheme which would provide a perennial regulated flow of 1,200 cusecs to the Nizamsagar reservoir, thereby maintaining a high water level in the latter, and also permitting a higher draw-off in summer. Consequently, the firm capacity of the Nizamsagar station, now 3,000 kW only, will rise to 7,000 kW, and the annual output of energy would be increased by 36 million units.

The generating plant and switchgear are being supplied by The English Electric Co. Ltd., who will also supervise the erection of the plant and machines. British Insulated Callender's Cables Ltd. are the contractors for the supply and erection of the transmission line. Civil-engineering work is carried out departmentally. (*Indian Journal of Power and River Development*, Vol. 2, No. 12, November 1952, p. 7, 4 pp., 3 ff.)

Water Turbines and Storage Pumps

A brief outline is given of the calculation bases and research problems involved in the design and construction of modern water turbines and storage pumps. The values given in this article for calculation purposes are either mean values, or they have been determined so as to ensure a safe basis for design; they are intended as a kind of general guide, since bases of calculation vary from manufacturer to manufacturer.

The three main types of turbine are considered separately, together with their characteristics and problems; storage pumps are dealt with in the paragraph on Francis turbines. (P. U. Weber, *Technische Rundschau*, Bern, Vol. 45, No. 15b, April 15, 1953, p. 1, 6 pp., 19 ff.)

Tessin Development, Switzerland

The general meeting of the Swiss Association for Water Utilisation was held this year at Locarno on May 29. On this occasion, *Wasser- und Energiewirtschaft* issued a special number which contains a number of interesting articles devoted to water power development and water supply in the Tessin Canton:

"Water-power development in Tessin," by C. A. Giudici;

"The Maggia Power Plants," by Chief-Engineer Dr. A. Kaech, with a full description of the plants contributed by the Maggia Power Co., Locarno;

"Extension of the hydraulic works at the Ritom power plant of the Federal Railways," by Chief-Engineer P. Tresch;

"Energy transport across the Alps," by Ing. R. Gonzenbach;

"Hydrological conditions on the south slopes of the Alps," by Ing. C. Ghezzi and Professor F. Gygax;

"Regulation of Lake Maggiore," by A. Jaccard;

"Regulation of Lugano Lake," by L. Kolly;

"The waterway from Lake Maggiore to the Adriatic Sea," by Dr. C. Beretta.

(*Wasser- und Energiewirtschaft*, Vol. 45, No. 4-6, April-May-June 1953, 75 pp., 80 ff.)

Centenary of the Ecol Polytechnique of the Lausanne University

The *Bulletin Technique de la Suisse Romande* contributes the following articles on subjects connected with water power to this centenary:—

"Expansion of secondary power storage in Switzerland," by R. Thomann;

"Plants of the Société Romande d'Electricité," by P. Payot;

"Installations of the Compagnie Vaudoise des Forces Motrices des lacs de Joux et de l'Orbe, and their development," by R. Golay;

"Development of a new head at Clees sur l'Orbe," by René H. Lambert;

"Construction plant at the Grande Dixence," by J. Desmeules;

"Setting up of construction plants at high altitudes," by Jean-Emmanuel Dubochet;

"Civil-engineering contractors and the problems they have to face in hydro-electric development under present conditions," by Pierre Peitrequin;

"Setting up high-head hydro-electric power plants," by Pierre-H. Neeser;

"Capacity limit of water-wheel driven alternators," by Jean Schneider;

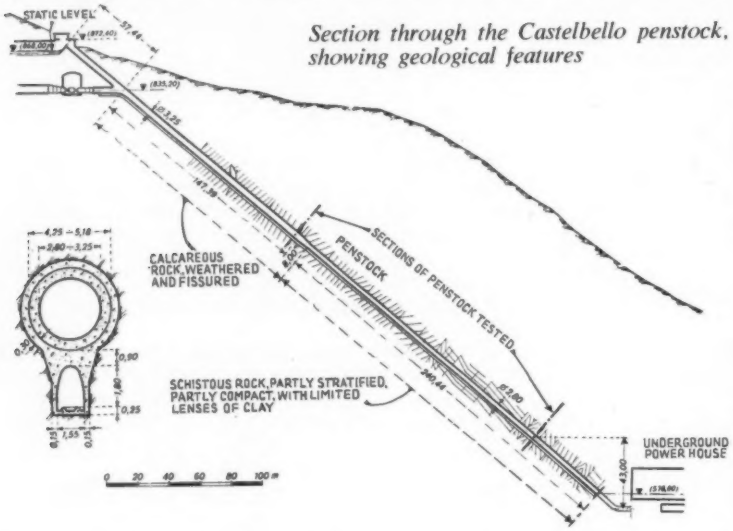
"Sluice-gate hoists," by J. Tache;

"Model tests applied to reinforced-concrete structures," by A. Villard.

This issue concludes with a short illustrated description of some of the laboratories and institutes of the Lausanne Ecole Polytechnique. (*Bulletin Technique de la Suisse Romande*, Vol. 79, No. 11/12, 13.6.1953, 128 pp., 214 ff.)

The Castelbello Penstock, Upper Adige

In its first part, this article deals with the calculation bases adopted, and the theoretical and experimental research carried out, in connection with the project of this reinforced-concrete penstock which has an aggregate length of 450 m., and is designed for a pressure of 300 metric tons per sq. m. at its downstream end. The nature of the rock, through which the penstock follows a straight course from top to bottom at a uniform gradient of 85 per cent., is stated in the appended diagram. The penstock is divided into two sections of which the upper one is 325 mm. in diameter and 147·39 m. in length, and the lower one 280 mm. in diameter and 240·44 m. in length, with an 8 m. long tapering connection between the two sections. At the top, the conduit extends 57·44 m. beyond the outlet of the pressure tunnel up to the surge chamber.


STATIC LEVEL
CALCAREOUS ROCK, WEATHERED AND FISSURED
PENSTOCK
SECTIONS OF PENSTOCK TESTED
SCHISTOUS ROCK, PARTLY STRATIFIED, PARTLY COMPACT, WITH LIMITED LENSES OF CLAY
UNDERGROUND POWER HOUSE
0 20 40 60 80 100 m

Section through the Castelbello penstock, showing geological features

The typical cross section shown at the left-hand bottom corner of the diagram consists of a 30 cm. outer layer of plain concrete, a 42·5 cm. intermediate layer of reinforced cement, previbrated and injected, which constitutes the main resisting element of the conduit, and a thin inner lining reinforced by several thicknesses of fine wire netting. In addition, a drainage channel, which forms an integral part of the structure, runs under the penstock along the whole of its length, starting from the downstream end of the pressure tunnel.

The tests carried out in August 1949, after the penstock had been put into operation, as well as the extensive tests carried out on models at the laboratory of the Milan Politecnico, are described and discussed in detail. A short stoppage of the plant in November 1950 gave the opportunity to effect comprehensive control tests. In the second part of the article, the two series of tests on site are compared. The results obtained were in full agreement with those supplied by the model tests, and established the excellent behaviour of the penstock in actual practice. (Prof. Ing. Guido Oberti, *L'Energia Elettrica*, Vol. XXX, No. 5, May 1953, p. 269, 13 pp., 9 ff.)

The World Electrical Industry

A whole issue of *Quaderni* is devoted to a world survey of the electrical industry carried out by the various sections of the Research Department of the Edison Group. This survey comprises the following articles:—

"Tendencies in the consumption of power sources," considered from a strictly statistical viewpoint; the data given for the last forty years clearly demonstrate the continually decreasing importance of fossil fuel within the frame of world power production. Pit coal, which covered 90 per cent. of the world power consumption before World War I, represents now no more than about half of it.

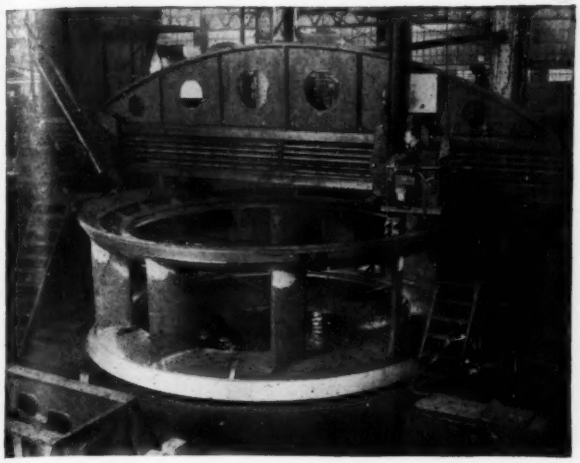
"Electric power production in 1952" examines data and events relating to last year, when world production reached 1,137,000 million kWh as compared to 460,000 million kWh in 1938.

That this increasing tendency is not likely to slow down in the near future is set forth in the following article, "Development programme of the electrical industry," which reviews development schemes planned and contemplated in all parts of the world, from the countries in the front line of world economy to those in Africa and Asia where industrial expansion is still in its infancy. The picture resulting from this brief but fairly comprehensive review shows that the expansion of electric power production remains one of the main factors of economic progress, as well in highly industrialised as in underdeveloped countries.

"Machinery and electrical plants in 1952" opens the more specifically technical part of the survey; the progress accomplished, recent achievements and those still at an earlier stage are examined, as well in thermic as in hydraulic power plants. The adoption of large-size generating units is underlined, and no less than three pages deal with the important problem of energy transmission, together with the delicate problems arising out of the increase of power and voltage.

After a review of the application of electric energy to lighting as well as to household implements and modern machine tools, the survey concludes with a study of the "Possibility of electric power production from new sources" in which the harnessing of heat from the earth or the sun, of winds and tides, as well as the utilisation of nuclear energy are discussed.

A complete list of the articles previously published in *Quaderni* on this subject is appended. The survey is completed by an excellent map and graphs in four colours. (*Quaderni di studi e notizie*, Vol. 9, No. 147, 16.5.1953, 65 pp., 18 ff.)



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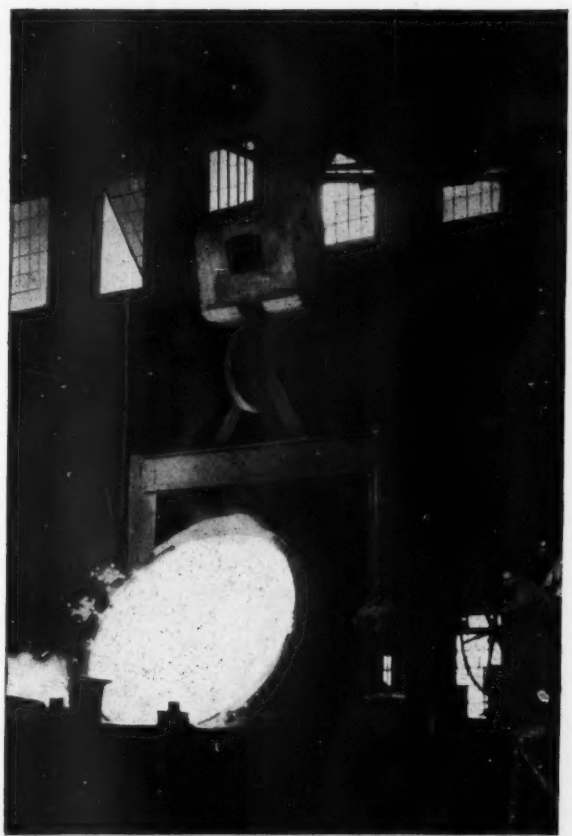

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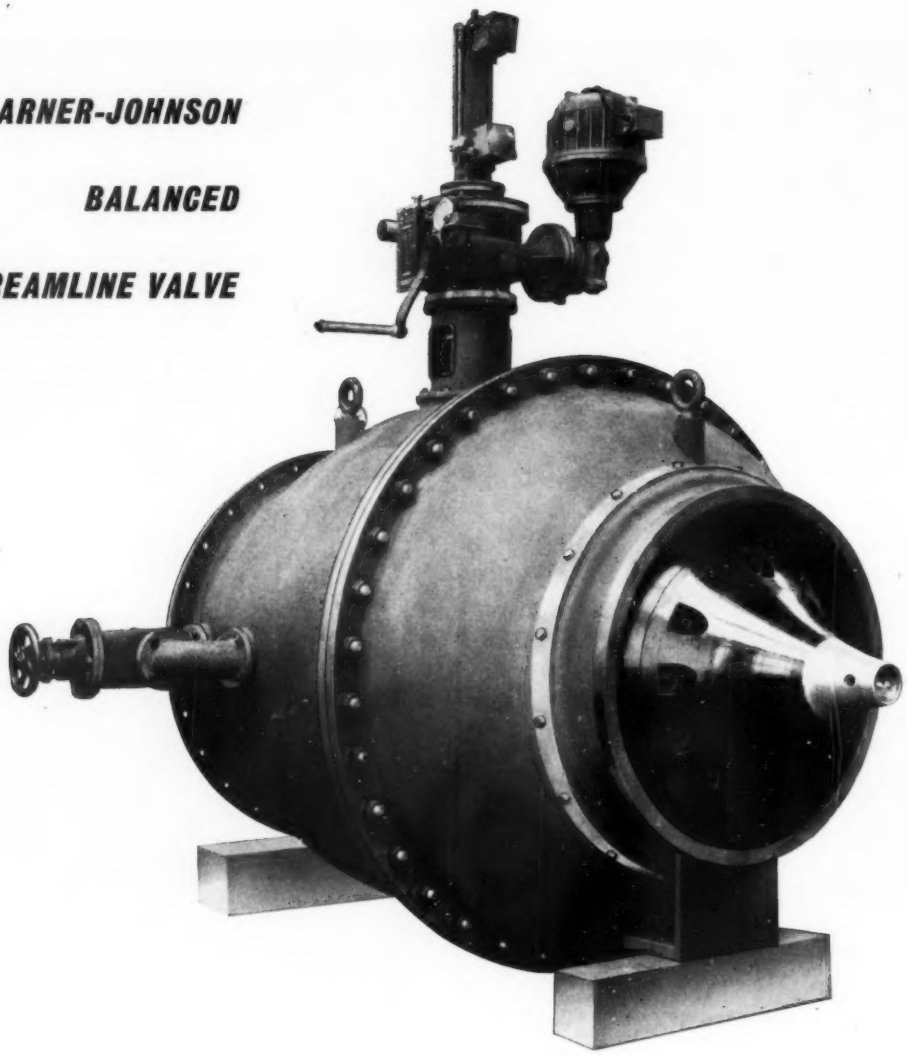

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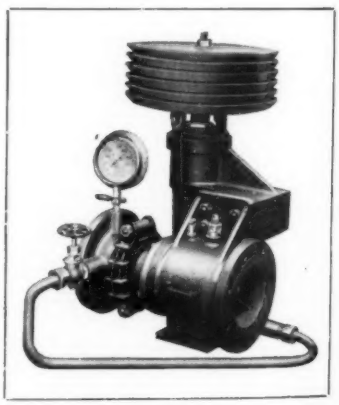

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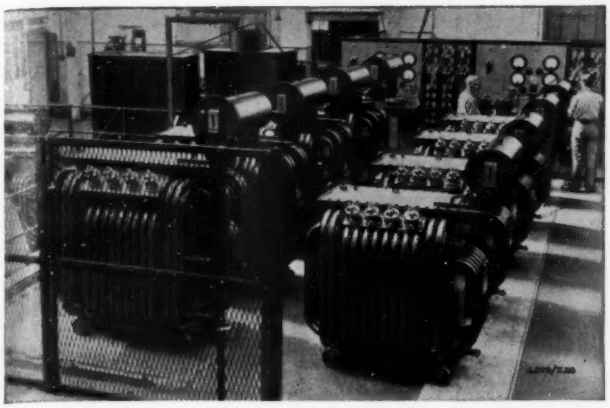

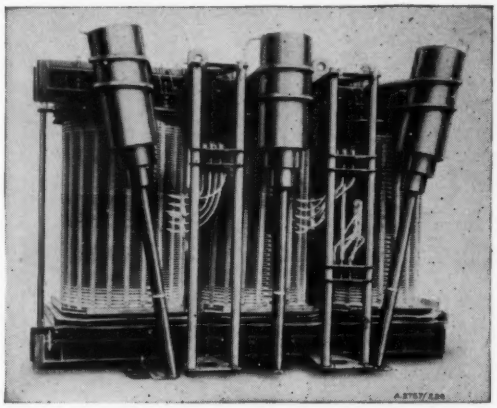

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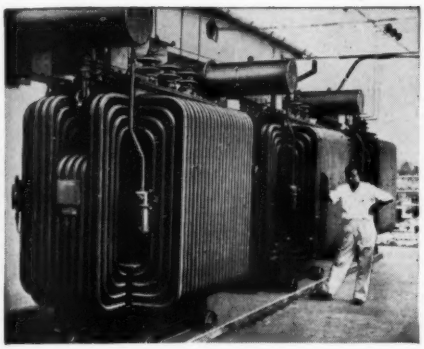

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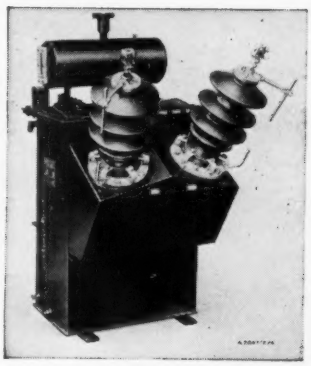

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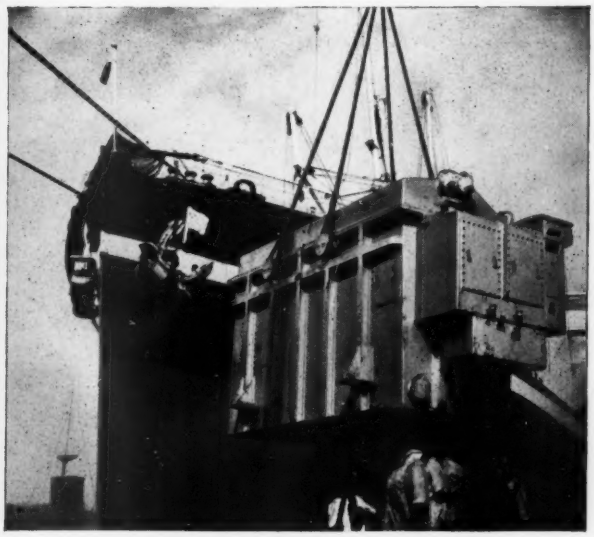

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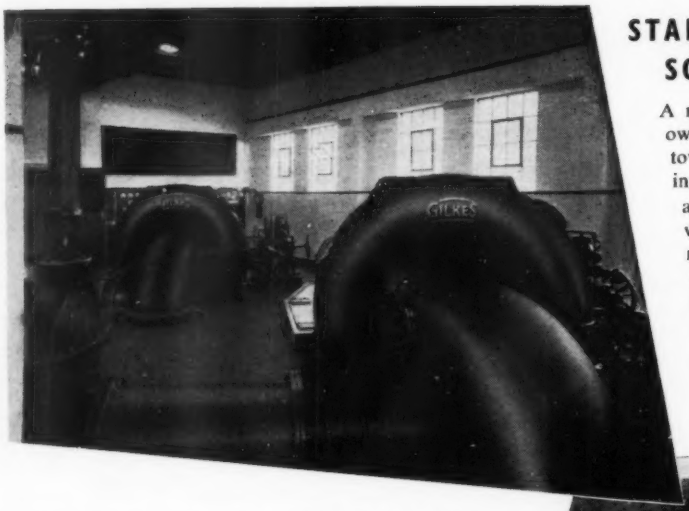

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Above: Interior, showing the two 725 B.H.P. GILKES Francis Turbines

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Right: Exterior of power station

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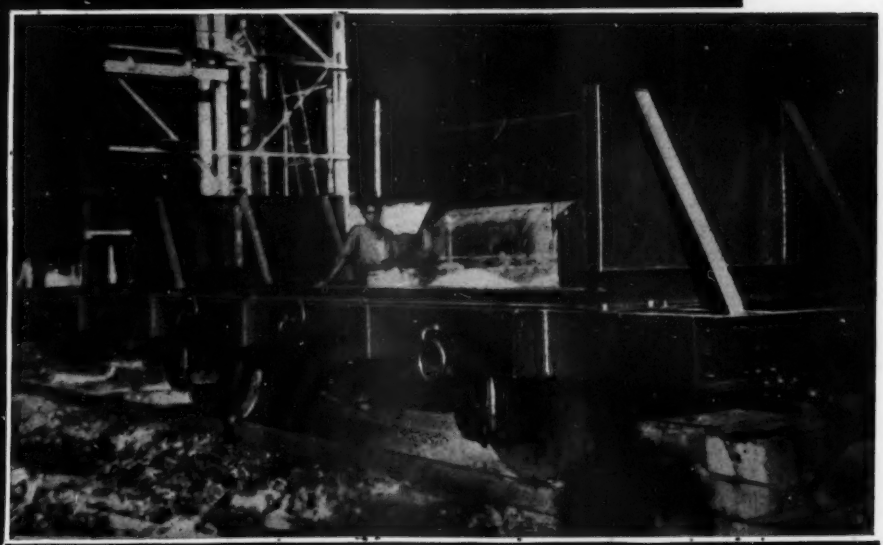

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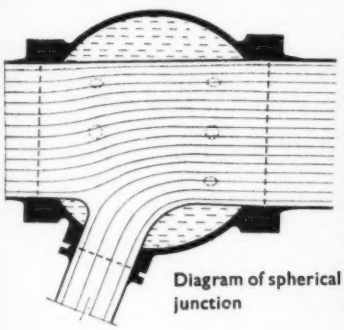

Diagram of spherical junction

Hydraulic test of a Ferrand patent manifold with high hydraulic efficiency

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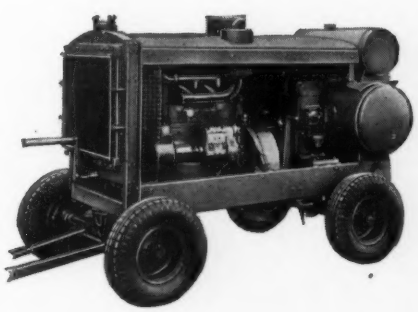

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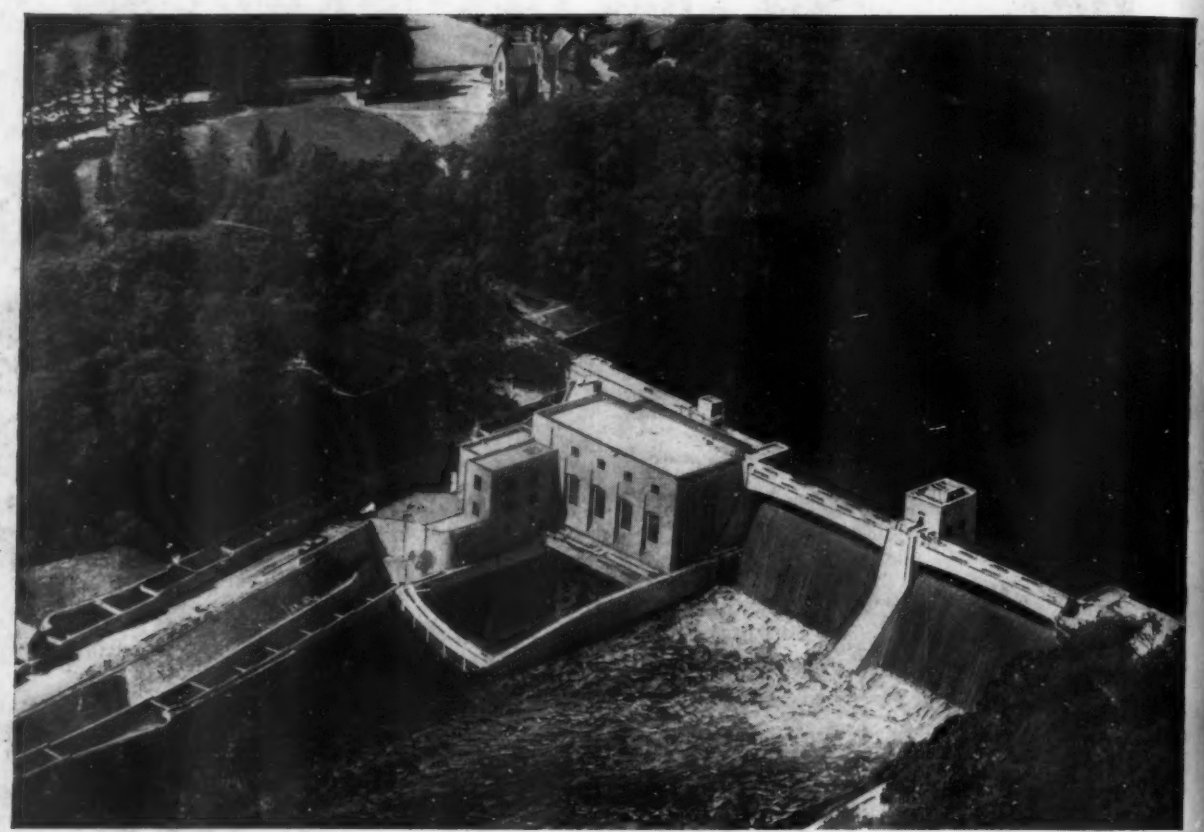

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